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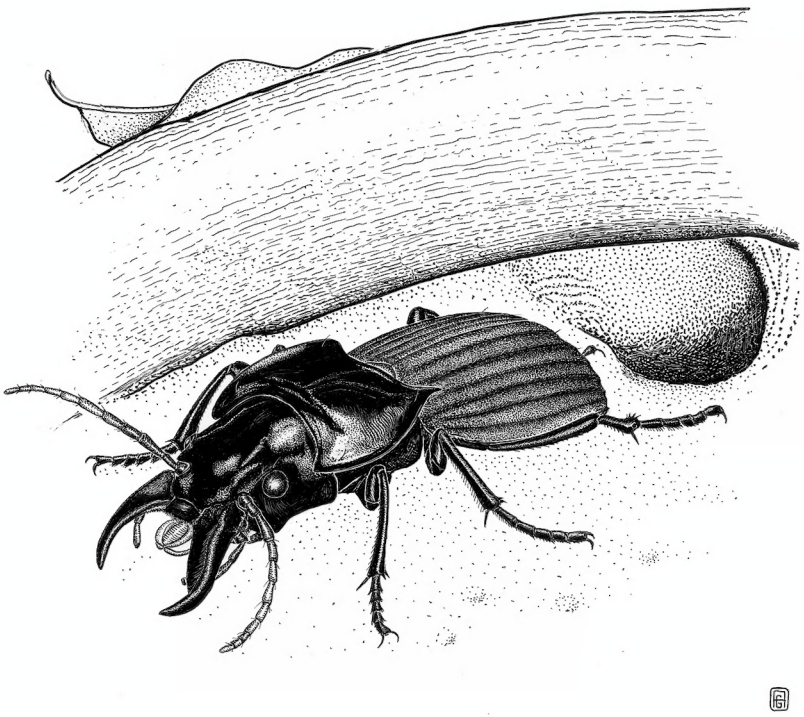

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COVER

The giant wingless carabid, *Nurus rex* Darlington 1961, at the entrance to its burrow under a rainforest tree root. The species occurs only in a small cap of rainforest on the summit of the 1000 m Mt Elliot, just south of Townsville, and was first collected by the noted Harvard biogeographer, Philip Darlington, when he made the first entomological ascent of the mountain in March 1958. It is the largest and most northerly of about a dozen species in its genus, all of which are now known to live in burrows with a cleared entrance court where they ambush passing invertebrates at night. Pen and ink drawing by Caloundra ESQ member, Dr Albert Orr, whose illustrated books on dragonflies and butterflies have won awards in Australia and overseas.

NOTES ON THE TORTRICIDAE (LEPIDOPTERA) OF FIJI, WITH DESCRIPTIONS OF A NEW SPECIES AND A NEW SUBSPECIES

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Abstract

A recent collection of moths from Fiji included 139 individuals of the family Tortricidae, representing 33 species. One new species, *Rhopobota splendida* and one new subspecies, *Cryptophlebia ombrodelta suvaensis*, are described and illustrated. Four additional species are noted as new records for Fiji: *Nesoscopa mesites* Razowski, 2014, *Capua zaphyrra* Meyrick, 1936, *Adoxophyes cyrtosema* Meyrick, 1886 and *Teleta talaris* (Durrant, 1915). For three species, *Adoxophyes mixtior* Razowski, 2016, *Atriscripta strigata* Razowski, 2016, and *Cryptophlebia emphyla* Razowski, 2016, the original descriptions are augmented to include both sexes and/or additional forms.

Introduction

Razowski (2016a, 2016b) discussed the Tortricidae from Fiji based on previously published records and specimens held in the U.S. National Museum of Natural History, Smithsonian Institution, Washington D.C. (Razowski 2016a) and the Natural History Museum, London (Razowski 2016b). In total, he treated 25 species previously recorded from Fiji and described four new genera and 41 new species. He also provided illustrations of adults and/or genitalia of a few previously described species to supplement published data. He also noted that there were six species recorded from Fiji that he was unable to examine. This adds up to a total of 72 species of Tortricidae recorded from Fiji. Razowski (2016b) noted that the Fijian fauna most closely resembles that of Queensland, Australia, with 11 species in common.

The two papers by Razowski have proven to be extremely useful as the basis for the present work. Thirty-three species of Tortricidae have been identified from survey work since 1991 and are treated here, including one new species and one new subspecies, plus a further four species that are new records for Fiji. It has also been possible to supplement the descriptions for three species by illustrating additional forms and/or describing the opposite sex when only one was previously available.

Materials and methods

A regular programme of light trapping was carried out during 1991-1998, with a small number of additional visits up to 2015, to sample the moth fauna at various lowland forest locations in eastern Viti Levu, Fiji. Sites included (with approximate geographical coordinates) the provinces of Serua (-18°09′, 178°01′), Namosi (-18°06′, 178°10′) and Tailevu (-17°55′, 178°30′) and in the general Suva area at Savura (-18°04′, 178°27′). Collecting also was conducted in suburban Suva (-18°08′, 178°28′). A small number of visits were also made to a coastal location in Cakaudrove Province in Vanua Levu

(-16°25′, 179°54′). These locations range in altitude from sea level to 200 m. Collecting also took place in montane forest in Naitasiri Province (-17°43′, 178°01′) at an altitude of 900 m. A battery-powered trap was employed, using a 6W actinic tube as the light source, which allowed easy access to remote locations.

All types and examples of newly described forms and sexes, plus genitalia slides, are deposited in the National Museums of Scotland, Edinburgh.

Systematics

The classification used here follows that of Razowski (2016a, 2016b).

Family Tortricidae

Subfamily Chlidanotinae

Tribe Chlidanotini

***Trymalitis macarista* Meyrick, 1934**

Material examined. Five specimens – 1 ♀ from Serua, 1 ♂ from Savura, 1 ♂ from suburban Suva and 1 ♂, 1 ♀ from Tailevu.

Subfamily Tortricinae

Tribe Schoenotenini

***Proactenis leucocharis* (Meyrick, 1933)**

Material examined. Two specimens – 1 ♂, 1 ♀ from Namosi.

Notes. The specimens agree with Meyrick's (1933) original description of *Tortrix leucocharis* and with his holotype as illustrated by Clarke (1958). However, the illustration in Razowski (2016a) appears to be that of a different species.

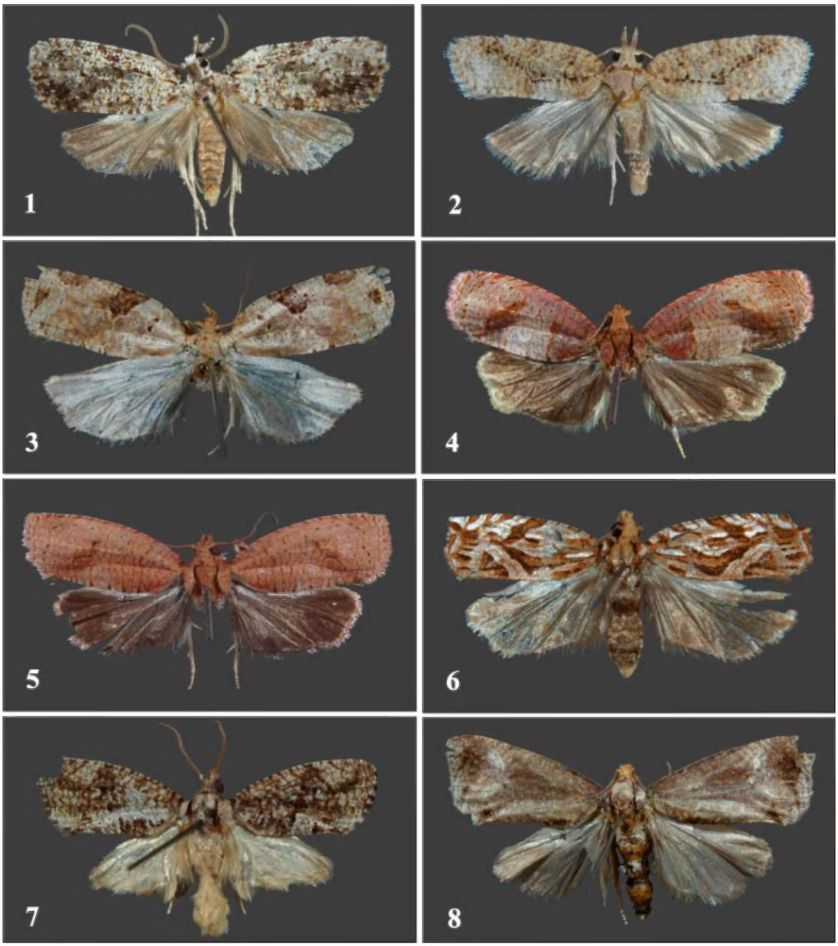
***Aphrozestis scoriopa* Meyrick, 1931**

= *Schoenotenes elaphrodes* Bradley, 1962

(Figs 1, 2)

Material examined. Two specimens – 1 ♂ from suburban Suva and 1 ♂ from Naitasiri.

Notes. This species was described from Lautoka, Fiji, a lowland city environment, or its immediate surroundings. The holotype was illustrated by Clarke (1958). Bradley (1962) described and illustrated *Schoenotenes elaphrodes* from the New Hebrides, now Vanuatu, from rain forest at an altitude of 400 m. Brown (2005) synonymised this species with *A. scoriopa.* There are considerable differences between Clarke's and Bradley's illustrations of the adults. However, the male genitalia as illustrated for both are similar and include a very striking aedeagus. The two specimens (Figs 1-2) in the current study are both males and reflect the difference between the two illustrated holotypes. Their genitalia are identical and agree with the



Figs 1-8. Tortricidae from Fiji: (1-2) *Aphrozestis scoriopa* Meyrick ♂, (3) *Adoxophyes mixtior* Razowski ♀, (4) *Atriscripta strigata* Razowski ♂, (5) *A. strigata* Razowski ♀, (6) *Rhopobota splendida* sp. n., holotype ♀, (7) *Cryptophlebia ombrodelta suvaensis* subsp. n., holotype ♂, (8) *C. emphyla* Razowski ♀.

genitalia illustrated by both Clarke and Bradley. The specimen in Fig. 1 resembles Clarke's illustration of Meyrick's type and was taken in montane forest at an altitude of 900 m. The specimen in Fig. 2 more closely resembles Bradley's type and was taken in suburban Suva. Both specimens show somewhat narrower wings than the illustrations of the two holotypes. However, based on the male genitalia there is no reason to question the identification or Brown's synonymy, but it would be interesting to analyse a larger sample, including females.

***Nesoscopa mesites* Razowski, 2014**

Material examined. Two specimens – 2 ♂♂ from Naitasiri.

Notes. Described from New Caledonia. Not previously known from Fiji.

Tribe undescribed

***Peraglyphis eida* Razowski, 2016**

Material examined. A single ♂ from Serua.

Tribe Archipini

***Capua endocypha* Meyrick, 1931**

Material examined. Five specimens – 2 ♂♂, 1 ♀ from suburban Suva and 2 ♀♀ bred from larvae collected at Matasawalevu Landing (-18°06′, 178°10′).

Notes. This species feeds on various mangroves. The Suva location is within 400 m of the coastal mangroves. The larvae were found on *Rhizophora samoensis* (Hochr.) Salvoza.

***Capua zapyrrha* Meyrick, 1936**

Material examined. A single ♀ from suburban Suva.

Notes. Described from Samoa. Not previously known from Fiji.

***Xenothictis atriflora* Meyrick, 1930**

= *Tortrix melananchis* Meyrick, 1930

Material examined. Three specimens – 1 ♂ from Namosi, 1 ♀ from Tailevu and 1 ♀ from Naitasiri.

Notes. Both this species and its synonym were described from Fiji.

***Adoxophyes cyrtosema* Meyrick 1886**

= *Adoxophyes novohebridensis* Diakonoff, 1961

Material examined. 15 specimens – 4 ♂♂, 2 ♀♀ from suburban Suva, 1 ♂, 1 ♀ from Namosi, 3 ♂♂, 2 ♀♀ from Tailevu and 2 ♂♂ from Cakaudrove.

Notes. Described from Tonga. Not previously known from Fiji. *Adoxophyes novohebridensis* was described from the New Hebrides, now Vanuatu.

***Adoxophyes mixtior* Razowski, 2016**

(Fig 3)

Material examined. Seven specimens – 3 ♂♂ from Savura, 2 ♂♂ from Namosi and 1 ♂, 1 ♀ from Naitasiri.

Notes. There is considerable variation in the extent and form of the dark markings of this species. Razowski (2016a) described the species from a single male of a very lightly marked form. He subsequently (Razowski 2016b) illustrated a much more heavily marked form and described the

female genitalia. Examples were taken of both these forms and two specimens represented a third form, described here.

Description of new form. An example of this form, a female taken in Naitasiri on 30.x.97, is illustrated in Fig. 3. It is similar to Razowski's well marked example, except the median fascia is much broader in the costal two fifths and is obsolescent in the basal three fifths; the subapical costal patch is also less elongated and extends further from the costa.

***Pteridoporthis euryloxa* Meyrick, 1937**

Material examined. A single ♂ from Namosi.

Subfamily Olethreutinae

Tribe Olethreutini

***Lobesia rhipidoma* (Meyrick, 1925)**

Material examined. A single ♀ from Naitasiri.

***Lobesia orthomorpha* (Meyrick, 1928)**

Material examined. A single specimen missing abdomen from Savura.

***Statherotis ancosema* (Meyrick, 1932)**

Material examined. 12 specimens – 4 ♂♂, 1 ♀ from Tailevu, 3 ♂♂, 1 ♀ from Namosi, 1 ♂, 1 ♀ from Savura and 1 ♂ from Serua.

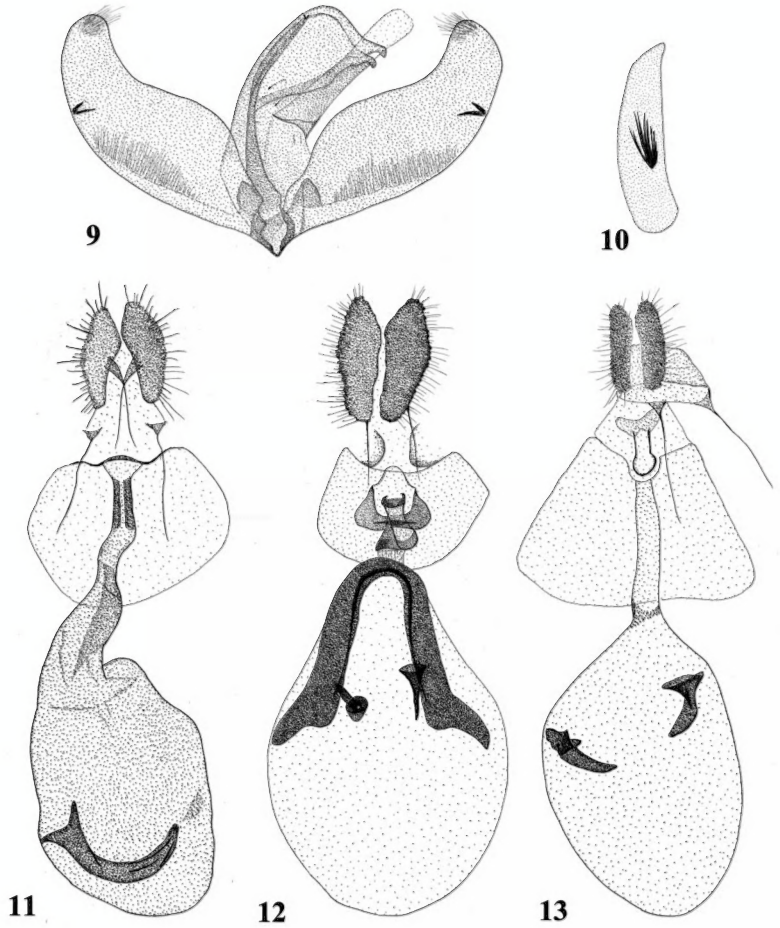
***Atriscripta strigata* Razowski, 2016**

(Figs 4-5, 9-11)

Material examined. 27 specimens – 6 ♂♂, 1 ♀ from Namosi, 3 ♂♂, 1 ♀ from Serua, 3 ♂♂ from Tailevu, 11 ♂♂, 1 ♀ from Savura Creek and 1 ♀ from suburban Suva.

Notes. This species was described by Razowski (2016b) from a single worn male and its genitalia illustrated. It is redescribed here from both the male and female. The four female specimens were associated with the males based on the similarity of forewing markings and their co-occurrence at the same locations and dates as males.

Redescription of male (Fig. 4). Head: vertex and labial palpi rich buff-brown. Thorax: dorsum with anterior part rich buff-brown, remainder rust-brown. Wingspan 18-21 mm. Forewing not expanding beyond middle; costa curved, especially basally; apex rounded, obtuse; termen curved obliquely inwards in posterior half. Ground colour pale cream-brown, sparingly irrorated with brown; markings mostly rust-brown, but in some specimens brownish; basal patch extending to almost one third, well defined in posterior four fifths; costal strigulae alternately very small and somewhat broader and longer, separated by ground colour; basal patch extending diffusely along costa to about one half; a diffuse median fascia extending from well defined spot in



Figs 9-13. Male and female genitalia: (9-11) *Atriscripta strigata* Razowski: (9) male genitalia; (10) aedeagus; (11) female genitalia. (12) *Rhopobota splendida* sp. n., female genitalia of holotype. (13) *Cryptophlebia emphyla* Razowski, female genitalia.

disc at one half, expanding to tornus; rust-brown interspersed with areas of grey; a series of eight small black equally spaced dashes or spots extending from above tornus to just short of costa, where it curves basad; a ninth continuing this sequence basad parallel to costa but more widely spaced; a subterminal line from costa, extending along two thirds of termen; cilia paler. Hindwing strongly excurved at M_3; uniform grey-brown; cilia somewhat paler. Abdomen: grey-brown. Genitalia (Figs 9-10) described and illustrated by Razowski (2016b: fig. 10).

Description of female (Fig. 5). Head: vertex and labial palpi reddish ochreous. Thorax: dorsum reddish ochreous. Wingspan 19-21 mm. Forewings: similar shape to male, but apex slightly more pointed. Ground colour pale reddish ochreous, irrorated with similar but darker; markings darker reddish ochreous; basal patch hardly visible except for a series of irrorations coalescing to form distal boundary; costal strigulae similar to male but smaller; median fascia similar to male but much less pronounced; series of black dots similar to male but none extended into dashes; subterminal line and cilia as in male. Hindwings: only slightly excurved at M_3; uniformly darker than male. Abdomen: grey-brown. Genitalia (Fig. 11) very similar to the generic description given by Horak (2006); sternum 7 shows a median excavation and is fused with the sterigma; ductus bursae relatively short and gradually widening throughout; basal one quarter with two parallel, longitudinal sclerotised areas; corpus bursae ovate, with a single, very large horn-shaped signum.

***Dudua aprobola* (Meyrick, 1886)**

= *Temnalopha metallota* Lower, 1901

Material examined. Six specimens – 1 ♂ each from Namosi, Serua, Tailevu and Savura and 1 ♂, 1 ♀ from suburban Suva.

***Dudua lamiana* Razowski, 2016**

Material examined. Two specimens – 1 ♀ each from Serua and Namosi.

***Teleta talaris* (Durrant, 1915)**

= *Argyroploce xanthogastra* Meyrick, 1921

Material examined. Three ♂♂ from Namosi.

Notes. Described from New Guinea. Robinson *et al*. (1994) noted its known range from Thailand through Indonesia to New Guinea. Not previously known from Fiji.

Tribe Bactrini

***Bactra venosana* (Zeller, 1847)**

= *Bactra banosii* Gozmany, 1960

= *Bactra geraropa* Meyrick, 1931

= *Bactra punctistrigana* Mabille, 1900

= *Bactra scythropa* Meyrick, 1911

= *Bactra truculenta* Meyrick, 1909

Material examined. Five specimens – 2 ♀♀ from Savura, 2 ♂♂ from Tailevu and 1 ♀ from Naitasiri.

Notes. This species is widespread throughout the Old World.

Tribe Enarmoniini

***Periphoeba adluminana* Bradley, 1957**

Material examined. A single ♂ from Tailevu.

Notes. Periphoeba adluminana was described from the Solomon Islands. Razowski (2016a) discussed this and two closely related species, *P. trepida* (Meyrick, 1911), described from Queensland, and *P. palmodes* (Meyrick, 1920), described from Sri Lanka. Brown (2005) synonymised *P. adluminana* with *P. palmodes.* However, Razowski (2016a) took *P. adluminana* out of this synonymy to refer to the Fiji material, although he left open the possibility that this could represent a new species. The name *P. adluminana* is retained here.

***Ancylis charisema* Meyrick, 1934**

Material examined. Three specimens – 2 ♂♂ from Tailevu and 1 ♂ from Namosi.

***Procoronis swinhoeiana* (Walsingham, 1890)**

= *Procoronis rhothias* Meyrick, 1911

Material examined. Ten specimens – 6 ♂♂, 2 ♀♀ from Tailevu and 2 ♂♂ from Namosi.

Tribe Eucosmini

***Rhopobota splendida* sp. n.**

(Figs 6, 12)

Type. Holotype ♀, FIJI: Viti Levu, Namosi Highlands, -18° 06′ 08″, 178° 10′ 30″, 17.vi.95, at light, J. Clayton.

Description. Female (Fig. 6). Head: vertex and labial palpi buff. Thorax: dorsum buff with darker shading laterally. Wingspan 19 mm. Forewings: costa moderately bowed, especially towards base, and slightly sinuate at apex; termen also slightly sinuate beneath apex, then convex and slightly angled inwards towards tornus; apex rectangular, slightly produced; costa and dorsum parallel except at base; ground colour iridescent silvery white; markings rich reddish brown; broad fascia extending and expanding distad from middle of wing at base to one quarter, where its width becomes one third the width of the wing, then bent downwards to almost meet dorsum at two fifths, then bent upwards and narrowing again to disc at three fifths; central area of fascia paler than borders; a break in fascia towards base leaving a narrow silvery white longitudinal mark to one fifth; median fascia from middle of costa, sloping distad also to disc at three fifths, where it joins with first fascia; subrectangular marks in disc on either side of median fascia; broad subterminal fascia, obsolescent at costa, from one quarter to near tornus, with some diffuse silvery colouration in central section; sequence of six horizontal black bars contained within this fascia; terminal fascia also

from one quarter, narrowing to a line near tornus; lozenge-shaped apical mark; sequence of costal strigulae in pairs of one broad and one small and narrow equally spaced; this sequence includes the costal portion of the median fascia. Hindwings: uniform pale grey; excurved at M_3. Abdomen: pale grey-brown. Genitalia (Fig 12) with sterigma sclerotized and fused with S7; a small curved sclerite below the ostium; ductus bursae extremely short; corpus bursae pear-shaped; two longitudinal sclerites from neck of bursa, extending half its length, connected by a curved transverse sclerite; two horn-shaped signa, one slightly larger than the other.

Male. Unknown.

Taxonomy. Horak (2006) discussed the generic characteristics of *Rhopobota* Lederer. In the female genitalia, the combination of a folded sclerite below the ostium, the corpus bursae with two long longitudinal sclerites connected by an arch-shaped sclerite at the neck of the bursa, and two horn-shaped signa, are diagnostic for *Rhopobota.* These features are present in *R. splendida.* Horak also referred to a dark band running from near the apex of the wing to the middle of the dorsum, where it is angled upwards to the base of the wing, together with the slightly projecting apex, as features of the genus, supporting the assignment to *Rhopobota.*

Diagnosis. The iridescent silver markings of this species serve to immediately distinguish it from all other *Rhopobota* species.

Etymology. The name *splendida* (Latin adjective) refers to the bright appearance of the species.

***Heleanna physalodes* (Meyrick, 1910)**

Material examined. A single ♀ from Serua.

Notes. Described from Sri Lanka as *Rhopobota physalodes.* According to Clarke (1976), its range extends from the Seychelles through South Asia and Indonesia to Fiji.

***Crocidosema lantana* Busck, 1910**

= *Epinotia corynetes* Diakonoff, 1982

= *Eucosma eridela* Turner, 1946

= *Eucosma perversa* Turner, 1946

= *Eucosma phaedropa* Tuener, 1946

= *Eucosma polyphaea* Turner, 1926

= *Eucosma tornocosma* Turner, 1946

Material examined. Two specimens – 1 ♂, 1 ♀ from Tailevu.

Notes. This widespread species is native to Mexico but has been introduced elsewhere to aid in the control of invasive *Lantana* species, its main foodplants. It has now spread to much of the Indian and Australian regions.

***Eccoptocera platamon* Razowski, 2016**

Material examined. A single ♂ from Namosi.

***Spilonota cryptogramma* Meyrick, 1922**

Material examined. Four specimens – 1 ♂, 1 ♀ from Tailevu, 1 ♀ from Serua and 1 ♂ from Savura.

***Strepsicrates glaucothoe* (Meyrick, 1927)**

= *Eucosma baryphragma* Meyrick, 1937

Material examined. A single ♀ from Savura.

Notes. Strepsicrates glaucothoe was described from Samoa; its synonym *Eucosma baryphragma* was described from Fiji.

Tribe Grapholitini

***Acanthoclita defensa* (Meyrick, 1922)**

Material examined. A single ♀ from Tailevu.

***Cryptophlebia ombrodelta* (Lower, 1898)**

= *Cryptophlebia carpophaga* Walsingham, 1900

Material examined. Three ♂♂ from suburban Suva.

Notes. Cryptophlebia ombrodelta is the most widely distributed species of this genus, occurring in Southeast Asia and the Pacific, ranging from India though to Australia and the Philippines. It is also recorded from Hawaii, presumed to be introduced. Some species of *Cryptophlebia* Walsingham are very variable, although known forms of *C. ombrodelta* show less variation. On the other hand, the closely related *C. illepida* Butler, known only from Hawaii, shows great variation such that Walsingham (1907) described four separate 'varieties'. In the male genitalia, the valves bear spine-like setae and the number and arrangement of these is diagnostic to species level.

The three males recorded here bear little superficial resemblance to known forms of *C. ombrodelta* but the genitalia are identical. They also show the large, dark hair tufts on the hind tibia, characteristic of *C. ombrodelta.* The species has not previously been recorded from Fiji. All the current specimens are of the same form and, as their appearance is so distinct from known forms of *C. ombrodelta,* it is described here as a new subspecies, *C. o. suvaensis.*

***Cryptophlebia ombrodelta suvaensis* subsp. n.**

(Fig. 7)

Types. *Holotype* ♂, FIJI: Viti Levu, Suva, -18° 07′ 31″, 178° 28′ 29″, 21.v.92, at light, J. Clayton. *Paratypes*: 2 ♂♂, same data as holotype, except 30.v.92 and 2.vi.92.

Description. Male (Fig. 7): Head: vertex and labial palpi pale grey-brown. Thorax: dorsum pale grey-brown. Wingspan 18-20 mm. Forewings: ground colour pale grey-brown, variably irrorated with brown and dark brown; markings dark brown; basal patch extending to almost half of wing and indicated in dorsal two fifths by sharp, dark brown terminal margin; triangular pre-tornal dorsal patch indicated by three dark brown marks at its apices; diffuse dark brown fascia from costa at three fifths extending approximately two thirds across wing to meet apex of tornal patch, widening to form a triangle; costal strigulae dark brown and alternately broad and narrow, the broader strigulae frequently joining with transverse irroration to extend up to one third across wing. Hindwings: pale grey-buff, slightly darker apically. Abdomen: pale buff, including anal tuft. Genitalia: valve with three large, strong spine-like setae, two on the ventral margin and one on the dorsal margin; these setae arranged to form the vertices of an almost equilateral triangle; an absence of small setae between these. These features are diagnostic for *C. ombrodelta.*

Female. Unknown.

Etymology. The name *suvaensis* relates to the fact that all the specimens were taken in Suva.

***Cryptophlebia repletana* (Walker, 1863)**

= *Argyroploce tetraploca* Meyrick, 1928

= *Argyroploce trichosoma* Meyrick, 1914

Material examined. Two ♂♂ from Naitasiri.

***Cryptophlebia pallifimbriana* Bradley, 1953**

Material examined. Three specimens – 1 ♀ each from Namosi, Tailevu and suburban Suva.

***Cryptophlebia vitiensis* Bradley, 1953**

Material examined. One ♂ from Tailevu and 1 ♀ from Namosi.

***Cryptophlebia emphyla* Razowski, 2016**

(Figs 8, 13)

Material examined. A single ♀ from Naitasiri.

Notes. Razowski (2016a) described and illustrated this species from two males. The specimen recorded here is a female and was assigned to *C. emphyla* based on the similarity in its markings and colouration. Its genitalia are typical of *Cryptophlebia*.

Description. Female (Fig. 8): Head: vertex and labial palpi pale buff. Thorax: dorsum pale grey. Wingspan 28 mm. Forewings: ground colour uniform pale grey-brown; no indication of basal patch; dark brown triangular, subtornal

dorsal patch clearly defined; shading in discal area and along costa from base to two thirds; diffuse subterminal fascia consisting of broad area of shading in costal half, narrowing to well defined line towards tornus. Hindwings: uniform pale grey. Genitalia (Fig. 13) with ostium consisting of straight section, with expanded, rounded termination, fitting into a median excavation in sternum 7; ductus bursae relatively short and expanding very slightly over its length; narrow band of scobination at the point where it joins corpus bursae; corpus bursae ovate, with two horn-shaped signa.

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THE ROVE BEETLE *PHILONTHUS ANTIPODUM* FAUVEL, 1877: A JUNIOR SYNONYM OF *PHILONTHUS UMBRATILIS* (GRAVENHORST, 1802) (COLEOPTERA: STAPHYLINIDAE: STAPHYLININAE)

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Abstract

Philonthus antipodum Fauvel, 1877 is placed in synonymy with *Philonthus umbratilis* (Gravenhorst, 1802), a rove beetle from the Palaearctic adventive in Australia. To fix the identity of *Philonthus antipodum* Fauvel, 1877, a lectotype is designated.

Introduction

Philonthus antipodum Fauvel, 1877 was originally described from Queensland and Victoria in eastern Australia (Fauvel 1877). Subsequently, Lea (1925) reported it from New South Wales, South Australia, Western Australia and Lord Howe Island. Preliminary study of an Australian specimen identified as *P. antipodum* in the Natural History Museum, London, suggested that *P. antipodum* could be a synonym of *Philonthus umbratilis* (Gravenhorst, 1802) (Jenkins Shaw and Solodovnikov 2016), a common West Palaearctic species that is already known as adventive in Australia, New Zealand and North America (Newton and Thayer 2005, Solodovnikov and Brunke 2016).

Following the study of type specimens of *Philonthus antipodum* and additional conspecific material from Australia, it is possible to confirm its synonomy with *Philonthus umbratilis.* In order to fix the identity of *P. antipodum*, a lectotype is designated here.

Methods and materials

Dry pinned specimens were studied and, where possible, males were dissected and their genitalia examined. Dissected genitalia and the terminal segments of the abdomen were stored under their respective specimens in capsules containing glycerine. Label data is repeated verbatim with a forward slash '/' indicating the separation of labels. Additional specimens identified as *Philonthus umbratilis* now bear my personal determination labels.

Specimens studied are deposited in the following institutions: AMS – Australian Museum, Sydney, Australia (Derek Smith, Chris Reid); ANIC – Australian National Insect Collection, CSIRO, Canberra, Australia (Cate Lemann); RBINS – Royal Belgium Institute of Natural Sciences, Brussels, Belgium (Yvonnick Gerard, Wouter Dekoninck).

Fig. 1. Male lectotype of *Philonthus antipodum* Fauvel, 1877, a synonym of *Philonthus umbratilis* (Gravenhorst, 1802).

***Philonthus umbratilis* (Gravenhorst, 1802)**

= *Philonthus antipodum* Fauvel, 1877, **syn. n**. (Fig. 1)

Type material examined. *Lectotype* ♂ (here designated): 'Australie, Gayndah / *antipodum* Fvl. / R.I.Sc.N.B. 17.479 Coll. et det. A. Fauvel / Ex-Typis / Syntype *Philonthus antipodum* Fauvel, 1877 J. Jenkins Shaw rev. 2017 / Lectotype *Philonthus antipodum* Fauvel, 1877 J. Jenkins Shaw des. 2017'. *Paralectotype* ♂ (here designated): 'Victoria / Coll. et. det. A. Fauvel *Philonthus antipodum* Fauv. R.I.Sc.N.B. 17.479 / Ex-Typis / Syntype *Philonthus antipodum* Fauvel, 1877 J. Jenkins Shaw rev. 2017 / Paralectotype *Philonthus antipodum* Fauvel, 1877 J. Jenkins Shaw des. 2017' (both in RBINS).

Additional material examined. 2 specimens (♂ on left) on one card/pin, '477, *Philonthus antipodum* Fvl, Id. By A.M. Lea / R. Murray, S. Australia, A.H. Elston / A.H. Elston Collection. / AMS K456697'; 1 ♂, '477, *Philonthus antipodum* Fvl / R. Murray, S. Australia, A.H. Elston / A.H. Elston Collection. / Australian Museum K456684'; 1 ♀, 'Murray R., South Australia, A.H. Elston / 477 *Philonthus antipodum* Fvl, Id. by A.M. Lea / A.H. Elston Collection / Australian Museum K456690' (in AMS); 1 ♂, 'S. Aust / Ex. Coll. S.A. Mus.'; 1 ♂, 'S. Australia / Ex. Coll. S.A. Mus / *Philonthus antipodum* Fvl Id. By A.M. Lea' (in ANIC); 1 ♂, 'Adelaide / Coll. et. det. A. Fauvel *Philonthus antipodum* Fauv. R.I.Sc.N.B. 17.479'; 1 ♂, 'Hobart, Tasmania J.J. Walker / Coll. et. det. A. Fauvel *Philonthus antipodum* Fauv. R.I.Sc.N.B. 17.479'; 1 ♀, 'Murray Bridge S. Aus / Reg. Mus. Hist. Nat. Belg. I.G. 9851. / *Philonthus antipodum* Fvl Id. by A. M. Lea'; 1 ♂, 'Murray Bridge S. Aus / Reg. Mus. Hist. Nat. Belg. I.G. 9851 / A. M. Lea., det. *Philonthus antipodum* Fauv.' (in RBINS).

Comments on the lectotype designation and new synonomy

Philonthus antipodum was originally described from 'Australie, Victoria; Queensland, Gayndah'. Since Fauvel (1877) did not specify the number of specimens on which he based his original description, two males from his collection in RBINS, with his handwritten identifications and the geographical labels matching the areas indicated in the original description, are here considered to be syntypes. Of them, a male with the more exactly specified geographic origin ('Australie, Gayndah' [Gayndah, a town in Queensland]) is designated as the lectotype. The external morphology and structure of the male genitalia of the lectotype and paralectotype leave no doubt that they are *Philonthus umbratilis*.

Discussion

The synonomy of a supposedly Australian endemic species of *Philonthus* with an adventive Palaearctic species has minor but important consequences for systematics and biogeography. The results highlight the relatively early introduction of a Palaearctic species into the Australian continent, presumably by European settlers. It is not clear when *Philonthus umbratilis* was introduced to Australia; however, given the description of *P. antipodum* in 1877, *P. umbratilis* must have been introduced to Australia some time prior to that date. There are certainly some endemic species among the 15 species of *Philonthus* recorded from Australia (Newton and Thayer 2005); however, a detailed study of this genus in Australia might prove that further described species are in fact misidentified introduced taxa and thus synonyms. A similar trend has been demonstrated already for New Zealand 'endemic' *Philonthus* (Solodovnikov and Brunke 2016).

Such a 'loss' of an 'endemic' *Philonthus* from these isolated southern landmasses reinforces an earlier noted pattern of a depauperate species diversity of that genus there. Poor representation of the mega-diverse genus *Philonthus* (1350 species globally according to Chani-Posse *et al*. 2017) in the south temperate areas of the world has been explained by the northern,

presumably Laurasia-derived origin of the entire subtribe Philonthina (*e.g.* Chatzimanolis *et al.* 2010, Brunke *et al.* 2016, Chani-Posse *et al.* 2017).

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A REVIEW OF THE INDO-AUSTRALIAN SUBGENERA *HEMINOTODACUS* DREW, *PARADACUS* PERKINS AND *PERKINSIDACUS* SUBGEN. N. OF *BACTROCERA* MACQUART (DIPTERA: TEPHRITIDAE: DACINAE)

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Abstract

The Indo-Australian subgenera *Heminotodacus* Drew (1 species) and *Paradacus* Perkins (7 species) of *Bactrocera* Macquart are reviewed and a new subgenus, *Perkinsidacus* **subgen. n.**, is proposed for two Australasian species: *Bactrocera banneri* White from Morotai, northern Moluccas and *B. coracinus* (Drew) [type species] from Papua New Guinea. These three subgenera belong in the *Zeugodacus* group of subgenera and are distinguished by the presence of 2 pairs of scutellar setae and no medial yellow vitta on the scutum. A key to the ten species placed in these three subgenera is included.

Introduction

This is the seventh in a series of papers reviewing the subgenera of the economically important fruit fly genus *Bactrocera* Macquart, made possible by the revisions of Australasian and Southeast Asian species by Drew (1989) and Drew and Romig (2013) respectively. This paper deals with subgenera *Heminotodacus* Drew and *Paradacus* Perkins, which were considered by Hancock and Drew (2015) to contain one and six described species respectively, distributed primarily in Wallacea and New Guinea but with an outlying species in India and Sri Lanka; an additional species from Papua Province, Indonesia (White and Evenhuis 1999) was overlooked. Two additional species from eastern Indonesia (Maluku) and Papua New Guinea, included by Drew (1989) or Drew and Romig (2013, 2016) in subgenus *Paratridacus* Shiraki, are transferred here to the new subgenus *Perkinsidacus* **subgen. n.** All three subgenera belong in the *Zeugodacus* group of subgenera as defined by Drew (1989) and are united by the presence of 2 pairs of scutellar setae plus lack of a medial yellow vitta on the scutum. No host plants are known for any of the ten included species and only two have been recorded at a male attractant (cue lure).

Genus *Bactrocera* Macquart

Subgenus *Heminotodacus* Drew

Heminotodacus Drew, 1989: 15. Type species *Bactrocera dissidens* Drew, 1989, by original designation.

Definition. Abdominal sternite V of male with a shallow posterior emargination; posterior lobe of male surstylus long and narrow; pecten of cilia present on abdominal tergite III of male; postpronotal seta present; supra-alar setae absent; prescutellar acrostichal setae present; two pairs of scutellar setae; scutum with medial postsutural yellow vitta absent.

Response to male lures. None known (Drew 1989).

Comments. *Heminotodacus* differs from other *Zeugodacus* group subgenera in the combination of postpronotal seta present, medial yellow vitta on the scutum absent, 2 pairs of scutellar setae and male pecten present. The postpronotal seta is placed centrally, differing from the posterolateral placement seen in subgenus *Notodacus* Perkins (*Melanodacus* group of subgenera: see Hancock and Drew 2017) and this character is thus regarded as homoplasious.

B. (*Heminotodacus*) *dissidens* Drew

Bactrocera (*Heminotodacus*) *dissidens* Drew, 1989: 187. Type locality Bulolo, Papua New Guinea.

Distribution. Papua New Guinea (known only from the Bulolo district, Morobe Province).

Comments. This species was distinguished by Drew (1989) by the presence of a postpronotal seta, face fulvous without dark spots, scutum with a lateral yellow vitta joining the postpronotal and notopleural lobes and a broad but incomplete transverse fuscous band across the wing. For a detailed description and illustration see Drew (1989).

Subgenus *Paradacus* Perkins

Paradacus Perkins, 1938: 143. Type species *Paradacus fulvipes* Perkins, 1938, by original designation.

Definition. Abdominal sternite V of male with a shallow posterior emargination; posterior lobe of male surstylus long and narrow; pecten of cilia present on abdominal tergite III of male; postpronotal seta absent; supra-alar setae present; prescutellar acrostichal setae present or absent; two pairs of scutellar setae; scutum with medial postsutural yellow vitta absent.

Response to male lures. Cue lure (2 species) or no response known (5 species) (Drew and Romig 2013, White and Evenhuis 1999).

Included species. *Bactrocera* (*P.*) *angustifinis* (Hardy), *B.* (*P.*) *areolata* (Walker), *B.* (*P.*) *duplicata* (Bezzi), *B.* (*P.*) *fulvipes* (Perkins), *B.* (*P.*) *hancocki* Drew & Romig, *B.* (*P.*) *magnicauda* White & Evenhuis and *B.* (*P.*) *urens* White.

Comments. *Paradacus* is distinguished from other *Zeugodacus* group subgenera by the combination of postpronotal seta absent, medial yellow vitta on the scutum absent, 2 pairs of scutellar setae and male pecten present. The lateral postsutural vittae, when present, extend anterior to the suture as small spots; when absent a triangular extension from the notopleural lobe is present. Known females (except *B. duplicata*) have an exceptionally long and narrow oviscape. Hancock and Drew (2015) transferred *B. terminifer* (Walker) to subgenus *Parazeugodacus* Shiraki and the three Papua New

Guinean species included by Drew (1989) to subgenus *Zeugodacus* Hendel; the fourth species included by Drew (1989), the Moluccan *B. perplexa* (Walker), was transferred to subgenus *Zeugodacus* by Drew and Romig (2013). For detailed morphological descriptions and illustrations of the Southeast Asian and Wallacean species see Drew and Romig (2013) and for an illustrated key see Drew and Romig (2016). The remaining species, *B. magnicauda*, was described and illustrated by White and Evenhuis (1999).

B. (*Paradacus*) *angustifinis* (Hardy)

Dacus (*Paradacus*) *angustifinis* Hardy, 1982: 197. Type locality Lindu Valley, central Sulawesi, Indonesia.

Bactrocera (*Paradacus*) *angustifinis* (Hardy): Norrbom *et al.* 1999: 99; Drew and Romig 2013: 219.

Distribution. Indonesia (Sulawesi).

Male lure. Cue lure.

Comments. This species is known only from males. The scutellum has a broad black basal band.

B. (*Paradacus*) *areolata* (Walker)

Dacus areolatus Walker, 1861: 295. Type locality Batchian, northern Moluccas, Indonesia.

Dacus (*Paradacus*) *areolatus* Walker: Hardy 1959: 163.

Bactrocera (*Paradacus*) *areolata* (Walker): Norrbom *et al*. 1999: 99; Drew and Romig 2013: 220.

Distribution. Indonesia (Bacan and Seram Islands, northern and southern Maluku: White and Evenhuis 1999).

Comments. This species is known from two females and differs from the others in the subgenus by its fulvous scutum and extensive wing pattern. The oviscape is at least as long as the abdomen.

B. (*Paradacus*) *duplicata* (Bezzi)

Chaetodacus duplicatus Bezzi, 1916: 107. Type locality Pachmarhi, central India.

Dacus (*Zeugodacus*) *duplicatus* Bezzi: Hardy 1977: 57.

Bactrocera (*Zeugodacus*) *duplicata* (Bezzi): Norrbom *et al*. 1999:102.

Bactrocera (*Paradacus*) *duplicata* (Bezzi): Drew and Romig 2013: 238.

Distribution. India (Madhya Pradesh and Karnataka) and Sri Lanka.

Comments. This species is known from both sexes. The female has a short oviscape.

B. (*Paradacus*) *fulvipes* (Perkins)

Paradacus fulvipes Perkins, 1938: 143. Type locality Bettotan, nr Sandakan, Sabah, Malaysia.

Dacus (*Paradacus*) *fulvipes* (Perkins): Hardy and Adachi 1954: 155; Hardy 1974: 20.

Bactrocera (*Paradacus*) *fulvipes* (Perkins): Norrbom *et al*. 1999: 99; Drew and Romig 2013: 221.

Distribution. East Malaysia (Sabah) and Indonesia (northern Sulawesi). Hardy (1974) recorded a female from Batangas, Luzon, Philippines that appears to belong here.

Comments. This species is known from both sexes; Drew and Romig (2013) recorded the male holotype from Sabah and a female from Sulawesi. The female oviscape is at least as long as the abdomen.

B. (*Paradacus*) *hancocki* Drew & Romig

Bactrocera (*Paradacus*) *hancocki* Drew and Romig, 2013: 223.

Distribution. Indonesia (southern Sulawesi).

Male lure. Cue lure.

Comments. This species is known only from males. The scutum lacks postsutural lateral yellow vittae but a triangular presutural vitta is present from the notopleural lobe. The scutellum has a large black subapical patch.

B. (*Paradacus*) *magnicauda* White & Evenhuis

Bactrocera (*Paradacus*) *magnicauda* White and Evenhuis, 1999: 517. Type locality Nabire, [Papua Province], Indonesia.

Distribution. Indonesia (Papua Province).

Comments. This species is known from a single female, which has the oviscape about as long as the abdomen.

B. (*Paradacus*) *urens* White

Bactrocera (*Paradacus*) *urens* White, in White and Evenhuis 1999: 518. Type locality Buru, Moluccas, Indonesia.

Distribution. Indonesia (Buru Island, southern Maluku).

Comments. This species is known from a single female, which has the oviscape at least as long as the abdomen.

Subgenus *Perkinsidacus* subgen. n.

Type species: *Dacus coracinus* Drew, 1971, by present designation.

Definition. Abdominal sternite V of male with a shallow posterior emargination; posterior lobe of male surstylus long and narrow; pecten of cilia absent on abdominal tergite III of male; postpronotal seta absent; supra-alar setae present; prescutellar acrostichal setae present; two pairs of scutellar setae; scutum with medial postsutural yellow vitta absent.

Response to male lures. None known (Drew 1989, Drew and Romig 2013).

Etymology. Named after Frederick Athol Perkins (1897-1976), a pioneer in the study of Australasian Dacinae and describer of six currently accepted subgenera of *Bactrocera*.

Included species. *Bactrocera* (*P.*) *banneri* White and *B.* (*P.*) *coracinus* (Drew), both transferred from subgenus *Paratridacus* Shiraki.

Comments. *Perkinsidacus* is distinguished from other *Zeugodacus* group subgenera by the combination of postpronotal seta absent, medial yellow vitta on the scutum absent, 2 pairs of scutellar setae and male pecten absent. The Philippine subgenus *Nesodacus* Perkins also lacks the male pecten and medial vitta but it has only 1 pair of scutellar setae and also lacks prescutellar acrostichal setae. The lateral postsutural vittae do not extend anterior to the suture as small spots or vittae, further distinguishing this subgenus from the otherwise similar *Heminotodacus* and *Paradacus* (and also from *Nesodacus*).

Fig. 1. *Bactrocera (Perkinsidacus) coracinus* (Drew), dorsal view of holotype male. Photo by Geoff Thompson © Queensland Museum, Brisbane.

B. (*Perkinsidacus*) *banneri* White

Bactrocera (*Paratridacus*) *banneri* White, in White and Evenhuis 1999: 520. Type locality Morotai I., Moluccas, Indonesia.

Distribution. Eastern Indonesia (Morotai Island, northern Maluku).

Host plant. Unknown.

Comments. For a detailed description and illustration see Drew and Romig (2013).

B. (*Perkinsidacus*) *coracinus* (Drew) (Fig. 1)

Dacus (*Paratridacus*) *coracinus* Drew, 1971: 46. Type locality Bainyik, Sepik district, Papua New Guinea.

Bactrocera (Paratridacus) coracinus (Drew): Drew 1989: 198.

Distribution. Papua New Guinea (East and West Sepik Provinces).

Host plant. Unknown.

Comments. Drew (1972) noted that the male posterior surstylus lobes were produced but shorter than in *Zeugodacus* group subgenera such as *Austrodacus* Perkins and placed this species in the same subgenus as *B.* (*Paratridacus*) *expandens* (Walker). However, the lobes are long, narrow and directed posteroventrally, as in all other *Zeugodacus* group subgenera, rather than the broad, posteriorly directed lobes seen in typical *Paratridacus* Shiraki (see Fig. 1 in Hancock and Drew 2016). About as long as the width of the surstylus, the posterior lobes closely resemble those of *Parasinodacus* Drew & Romig [*cf.* Fig. 12f in Hardy (1973) of *B. (P.) cilifera* (Hendel)]. The holotype of *B. coracinus* (Fig. 1) is in the Queensland Museum, Brisbane and has been examined for this study; the surstylus lobes are clearly visible. For a detailed description and illustration see Drew (1971, 1989).

Key to species of *Heminotodacus*, *Paradacus* and *Perkinsidacus*

1 Scutum with postpronotal seta present and postpronotal and notopleural lobes connected by a lateral yellow vitta; wing with an incomplete transverse fuscous band (absent from costa to vein R_{4+5}) enclosing both R-M and DM-Cu crossveins; abdomen orange-brown with a fuscous medial vitta running its entire length [Papua New Guinea (Morobe Province)] ..... subgenus *Heminotodacus* Drew ... *B.* (*H.*) *dissidens* Drew

– Scutum with postpronotal seta absent and postpronotal and notopleural lobes not connected by a lateral yellow vitta; wing not as above; abdomen without a fuscous medial vitta 2

2 Scutum with lateral postsutural vittae present but not extending anterior to suture as small spots; abdomen with pecten of cilia absent in males; abdominal tergites I+II entirely black; fore and mid femora entirely black ..... subgenus *Perkinsidacus* **nov.** ... 3

– Scutum with either lateral postsutural vittae extending anterior to suture as small spots or with lateral postsutural vittae absent and a triangular vitta along suture from notopleural lobe; abdomen with pecten of cilia present in males; abdominal tergites I+II not entirely black, at least with posterior margin broadly fulvous; fore and mid femora usually not entirely black ..... subgenus *Paradacus* Perkins ... 4

3 Wing with a broad costal band reaching vein R_{4+5} and an oblique transverse band across R-M crossvein and apical part of cell dm to DM-Cu crossvein; anepisternal yellow stripe not reaching postpronotal lobe [Papua New Guinea (East and West Sepik Provinces)] .... *B.* (*Pe.*) *coracinus* (Drew)

– Wing with costal band absent beyond apex of vein R_1 and without an oblique transverse band across R-M crossvein to DM-Cu crossvein; anepisternal yellow stripe reaching postpronotal lobe [eastern Indonesia (Morotai I., northern Maluku)] ..... *B.* (*Pe.*) *banneri* White

4 Scutum with lateral postsutural vittae absent and a triangular vitta from notopleural lobe along suture present; scutellum with a black subapical patch; fore femora entirely and mid femora almost entirely fuscous [Indonesia (southern Sulawesi)] ..... *B.* (*Pa.*) *hancocki* Drew & Romig

– Scutum with lateral postsutural vittae present and extending anterior to suture as small spots; scutellum without a black subapical patch; fore and mid femora broadly fulvous at least basally 5

5 Scutum fulvous; wing with an extensive fuscous pattern across entire disc [eastern Indonesia (Bacan and Seram Is, northern and southern Maluku)] ..... *B.* (*Pa.*) *areolata* (Walker)

– Scutum black; wing with fuscous pattern restricted to costal band and anal streak 6

6 Scutellum with a broad black basal band; fore and mid femora black on at least apical two-thirds, fulvous basally; abdomen mostly black [Indonesia (Sulawesi)] ..... *B.* (*Pa.*) *angustifinis* (Hardy)

– Scutellum with a very narrow black basal band; fore and mid femora largely fulvous, at least on basal two-thirds; abdomen often largely fulvous 7

7 Abdomen largely black; anepisternal yellow stripe broad, reaching postpronotal lobe dorsally [India and Sri Lanka] .... *B.* (*Pa.*) *duplicata* (Bezzi)

– Abdomen largely fulvous; anepisternal yellow stripe narrow, not reaching postpronotal lobe dorsally 8

8 Anepisternal yellow stripe reaching almost to anterior notopleural seta dorsally; wing with costal band very faint and not broadly expanded

apically; face without a pair of black spots [eastern Indonesia (Buru I., southern Maluku)] ..... *B.* (*Pa.*) *urens* White

– Anepisternal yellow stripe not or barely wider than notopleural lobe dorsally; wing with costal band distinct and broadly expanded apically; face with or without a pair of black spots 9

9 Face with a pair of black spots; wing with apical expansion of costal band faint towards and across apex of vein M; abdomen with a black transverse band across base of tergite III [East Malaysia (Sabah), Indonesia (northern Sulawesi) and possibly Philippines (Luzon)] .... *B.* (*Pa.*) *fulvipes* (Perkins)

– Face without black spots; wing with apical expansion of costal band dark to and across vein M into cell m; abdomen without a black transverse band across base of tergite III [eastern Indonesia (northern Papua Province)] ..... *B.* (*Pa.*) *magnicauda* White & Evenhuis

Discussion

Six of the ten species treated here occur in Wallacea (Zone C of Hancock and Drew 2015), five of them being endemic. Three of the remaining four species, *B.* (*Heminotodacus*) *dissidens*, *P.* (*Paradacus*) *magnicauda* and *B.* (*Perkinsidacus*) *coracinus*, are known only from the island of New Guinea (Zone D), while the latter's sister-species, *B.* (*Pe.*) *banneri*, is known only from northern Maluku (Moluccas). Only a single species has been recorded from South or Southeast Asia proper – *B.* (*Paradacus*) *duplicata* from India and Sri Lanka (Zone A).

Of the five Wallacean species of *Paradacus*, *B.* (*Pa.*) *angustifinis* and *B.* (*Pa.*) *hancocki* are endemic to Sulawesi, while *B.* (*Pa.*) *areolata* and *B.* (*Pa.*) *urens* are known only from Maluku. Only *B.* (*Pa.*) *fulvipes* has a wider distribution, being known from northern Sulawesi plus neighbouring Sabah on the island of Borneo and possibly Luzon in the Philippines. The latter record was collected in August 1945 and is possibly mislabelled, although the Sulawesi and Sabah records are from areas on the periphery of the Philippines and the Luzon record might well be correct.

The exceptionally long oviscape in *B.* (*Pa.*) *areolata*, *B.* (*Pa.*) *fulvipes*, *B.* (*Pa.*) *magnicauda* and *B.* (*Pa.*) *urens* indicates a close relationship, these four species occurring largely allopatrically in northern and southern Maluku, northern Sulawesi-Sabah-?Philippines, northern Papua Province and southern Maluku respectively; *B.* (*Pa.*) *areolata*, with its fulvous scutum and extensive wing pattern, appears to be the most apomorphic of the four. The southern Sulawesian *B.* (*Pa.*) *hancocki*, with its largely fulvous abdomen and extensive wing pattern, might also belong in this group but the shape of the oviscape is unknown. *Bactrocera* (*Pa.*) *angustifinis* and *B.* (*Pa.*) *duplicata* both have largely black abdomens but the distributional anomaly seen in the latter species suggests that it might not belong in *Paradacus* but be an aberrant

species belonging elsewhere. *Bactrocera* (*Pa.*) *angustifinis* is known from throughout Sulawesi and thus occurs sympatrically with both *B.* (*Pa.*) *hancocki* and *B.* (*Pa.*) *fulvipes*; the shape of its oviscape is also unknown.

The scarcity of material and lack of any biological information on these species prohibits a fuller understanding of their relationships. No host plants are known but, as in the apparently related subgenera *Parasinodacus* Drew & Romig, *Nesodacus* Perkins and the Madagascan *Aglaodacus* Munro (all of which also lack the medial scutal vitta but have only 1 pair of scutellar setae), host plants are likely to be (at least primarily) non-cucurbitaceaous.

Acknowledgements

We thank Susan Wright and Geoff Thompson (Queensland Museum, Brisbane) for access to specimens and Figure 1 respectively.

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CORRECTION

In the review of subgenus *Bulladacus* Drew & Hancock by Drew and Hancock (2016), Table 1 incorrectly included Solomon Islands species in Zone F, rather than in Zone D as per the map of Hancock and Drew (2015). The corrected Table 1 is provided below. All 20 species are thus endemic to their particular biogeographic zones.

Table 1. Distribution of species in genus *Bactrocera* and subgenus *Bulladacus* in each biogeographic zone and percent endemism in *Bulladacus*. For a map of zones A-F see Hancock and Drew (2015).

Biogeographic Zone	**No. species of *Bactrocera***	**No. species of *Bulladacus***	**% Endemic *Bulladacus***
(A) Indian subcontinent	75	0	–
(B) South-East Asia	225	5	100
(C) Wallacea	124	0	–
(D) New Guinea + Solomons	170	11	100
(E) Australia	76	2	100
(F) South Pacific	59	2	100

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MERMITHID NEMATODES HOSTED BY *POLYRHACHIS* WEAVER ANTS (HYMENOPTERA: FORMICIDAE) IN NORTH QUEENSLAND, INCLUDING MULTIPARASITISM WITH AN INSECT PARASITOID

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Abstract

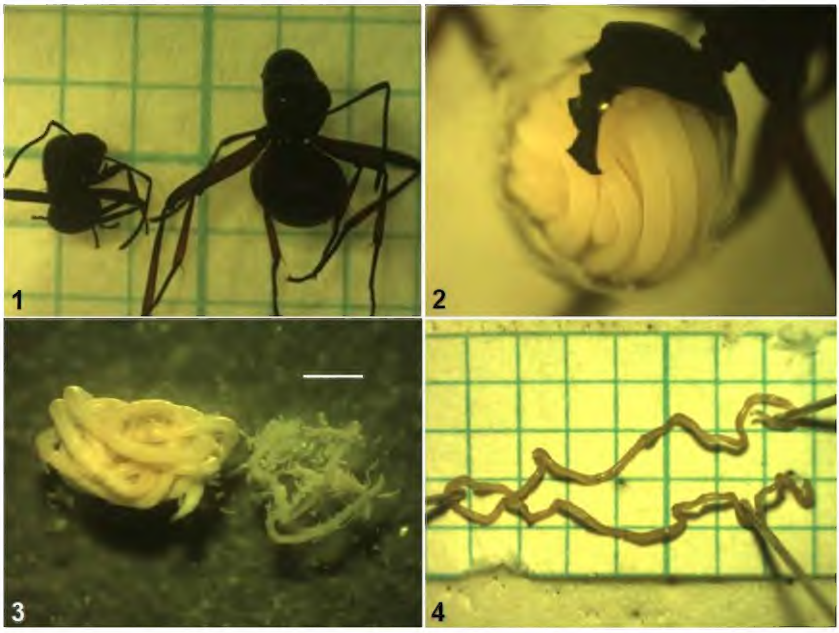
Nematodes of the family Mermithidae were found in arboreal weaver ants *Polyrhachis delecta* Kohout and *P. monteithi* Kohout from two locations in the wet tropics of North Queensland. Gigantism, often used as a sign of infection, was very rare in these ants; moreover, distension of the gaster was neither a necessary nor a sufficient indication that an ant was hosting a worm. Male ants were either disproportionately infected compared with other castes or possibly had their caste induced by the infection. *P. delecta* may be more vulnerable than other *Polyrhachis* Fr Smith species to mermithid infection. The dry tropics habitat of the Townsville district almost certainly reduced or precluded the activity of the nematode. No mermithids were found in samples of 11 other *Polyrhachis* species distributed across the region. Six cases of multiparasitism were found: single male host ants containing a mermithid nematode and the larvae of an insect parasitoid.

Introduction

Nematodes of the family Mermithidae are distributed world-wide, infect a broad range of insects and other invertebrates, and have been parasitoids of ants since the Eocene (40 mya) or earlier (Nickle 1972, Kaiser 1991, Poinar 1985, 2012). Coined by Wheeler in 1907, the term 'mermithergate' denotes a worker ant with an altered appearance due to hosting one or more mermithids. If the host ant is a female or male reproductive, it is called a mermithogyne and a mermithaner respectively. Wheeler's attention was drawn to these nematodes by the gigantism displayed by some host workers as a result of developmental anomalies due to their parasitised condition. Since then, abnormal size (and/or altered morphology, *e.g.* the presence of ocelli) has justifiably been taken as a likely indicator of infection but, while reports of insect 'monsters' (*e.g.* Perkins 1914) always raise the possibility of mermithid infection, and while altered appearances do sometimes apply to all infected individuals in a cohort and can be dramatic (Czechowski *et al.* 2007), this outcome is in fact comparatively rare, as the literature and the present findings attest. Abnormal behaviour, more notable among other insects hosting mermithids (Welch 1965), seems just as rare or rarer among ants, but has also been recorded (Maeyama *et al.* 1994). Up to 25% of ant workers can be infected (Czechowski *et al.* 2007), more in other insect taxa, *e.g.* 44% of black flies, *Simulium damnosum* Theobald, in Bulgaria (Gradinarov 2014) and 50% of midges, *Chironomus plumosus* Linnaeus, in Estonia (Krall 1959). The anatomical changes, when they occur, can lead to mistakes in indentification (Czechowski *et al.* 2007, Csősz 2012, Borowiec and Salata 2015).

The only previous records of mermithid infections in Australian ants are those reported by Wheeler (1933) for *Myrmecia forficata* Fabricius from Victoria, *Camponotus consobrinus* (Erichson) from Mt Kosciusko, New South Wales and the McPherson Range on the New South Wales / Queensland border and *C. claripes* Mayr, also from Mt Kosciusko. In addition, there is just one previous report (from Taiwan: Hung 1962) of mermithid infection in an ant of the genus *Polyrhachis*. Since most mermithids are host-specific (Poinar 2012, Rusconi *et al*. 2016), it is unlikely that the ones reported here from North Queensland are closely related to those found by Wheeler or Hung.

Hopes to the contrary notwithstanding (see *e.g*. Welch 1965), attempts to exploit mermithid nematodes as biological control agents have been largely unsuccessful but are still being pursued (see *e.g*. Bedding *et al*. 1993, Poinar *et al*. 2007).



Figs 1-4. Mermthergate and mermithids: (1) size comparison between the 'giant' *P. delecta* mermithergate from Little Crystal Creek and a typical nestmate worker, 2 mm background grid; (2) mermithid *in situ* in the gaster of a *P. delecta* worker, with most of the host's gastral tergites removed; (3) mermithid nematodes from different male hosts in a nest of *P. delecta*, the thinner worm assumed to be at an earlier moult stage, 1 mm scale bar; (4) unravelled mermithid from the 'giant' mermithergate from Little Crystal Creek, 2 mm background grid.

Materials and methods

The discovery in July 2016 of a 'giant' *P. delecta* worker containing a mermithid nematode (Fig. 1) prompted a search for others. The material for this search was obtained from 76 nests coming from two sources: (1) arboreal leaf nests and subterranean ground nests of seven *Polyrhachis* species, representing four subgenera, collected between 2009 and 2016 from the Townsville region (dry tropics); (2) exclusively arboreal leaf nests of six *Polyrhachis* species, representing four subgenera, collected between April and September 2016 from five locations in the wet tropics of northern Queensland (Table 1). In all, 4385 ants representing all adult castes and some male and worker pupae were dissected, 766 from the dry tropics locations and 3619 from the wet tropics sites.

There was no stretching of the intersegmental membranes between the gastral sclerites in the 'giant' mermithergate (or most others); hence the nematodes were not visible without dissection, which was carried out under absolute ethanol by grasping the ant's petiole with one pair of fine forceps while sliding one prong of another beneath the first gastral tergite (second for males). Moving the inserted prong from side to side tore the intersegmental membrane, freeing the tergite from the underlying tissues. The presence or absence of a mermithid nematode was evident at that stage, but in order to extract the worm and observe its effects, if any, on the gastral organs of the host, all tergites were removed from infected specimens (Fig. 2). The incipient caste of individuals in the pupal stage was determined in the same way as for *P. australis* Mayr (Downes, 2015). Extracted nematodes were initially kept in absolute ethanol.

Allowing the alcohol in a 5% glycerine/alcohol mixture (Lee's solution, from Baker and Poinar 1994) to evaporate slowly made the coils of an immersed worm more flexible and easier to unravel. Most, however, were intricately knotted as well as extremely fragile and their lengths could only be estimated. Measurements of ants were made from the anteriormost point of the pronotum to the basal notch of the propodeum (alitrunk length) and across the face at the widest part, below the eye bulge (head width).

The term 'gyne' is used here for both pre-mating alate female sexuals and post-mating dealate female sexuals (queens). Since 92% of this female reproductive caste were alates and no mermithids were found in any of either, nothing was to be gained by treating alates and dealates separately. Identifications of ants were made using the keys of Andersen (2000) and Kohout (2006, 2010, 2012, 2013). Voucher specimens of ants, mermithids and parasitoid larvae will be lodged with the Queensland Museum, Brisbane.

Results and discussion

Incidence, rates of infection, number per host, sizes, location and disposition of the mermithids

Table 1. Sources of material and numbers of mermithid worms found – g: gynes; m: males; mp: male pupae; w: workers; wp: worker pupae; n: number dissected; #mer: number of mermithids found. Excludes cases of multiparasitism.

Species	Location	coordinates	caste	n	#mer
delecta	Kuranda	16.82S, 145.63E	g	27	0
			m	106	0
			w	261	0
	Mission Beach	17.87S, 146.07E	g	216	0
			m	214	33
			w	645	8
			mp	51	4
			wp	14	1
	Lake Eacham	17.29S, 145.63E	g	30	0
			m	100	0
			w	120	0
	Crystal Creek	19.02S, 146.27E	g	100	0
			m	150	0
			w	450	3
unidentified*	Kuranda	16.82S, 145.63E	w	135	0
monteithi	Mission Beach	17.87S, 146.07E	g	19	0
			m	21	4
			w	105	0
	Lake Eacham	17.29S, 145.63E	g	20	0
			m	208	0
			w	100	0
mucronata	Mission Beach	17.87S, 146.07E	w	235	0
queenslandica	Mission Beach	17.87S, 146.07E	w	82	0
	Mount Elliot	19.41S, 147.01E	w	63	0
robsoni	Mission Beach	17.87S, 146.07E	w	26	0
	Cairns	16.90S, 145.75E	w	184	0
other**	Townsville		g,m,w	703	0

*under investigation; possibly a black variety of *P. yarrabahensis* Forel.

***ammon* (group), *appendiculata, australis, cupreata* (group), *obtusa* (group), *sokolova, yorkana.*

Mermithid nematodes were found in ants from two *P. monteithi* nests and one *P. delecta* nest taken at Mission Beach in June 2016, and from a second *P. delecta* nest taken at Little Crystal Creek in July 2016 (Table 1), the latter location producing the only worker that displayed ‘classic’ gigantism. Hence only 4 of 76 nests examined were infected with mermithids. None was found in ants from other wet tropics locations or from dry tropics locations and

none was found in any location two months later in September. Variability of this kind, *i.e.* in location, time and degree of infection, is consistent with some other examples of parasitoid infection, *e.g.* attacks by eucharitid wasps on *Ectatomma* F. Smith ants (Lachaud and Pérez-Lachaud 2015, Pérez-Lachaud *et al* 2010), where the impact on the ant population, though occasionally severe, remained relatively insignificant overall. Czechowski *et al.* (2007) found that among a number of nests of *Myrmica rubra* Linnaeus located along a riverside path in Poland, only one contained workers of unnatural appearance due to mermithid nematodes. Whether it was the only nest affected, however, is another question, since most infected *Polyrhachis* ants appear normal (see below), and the same may be true for other genera.

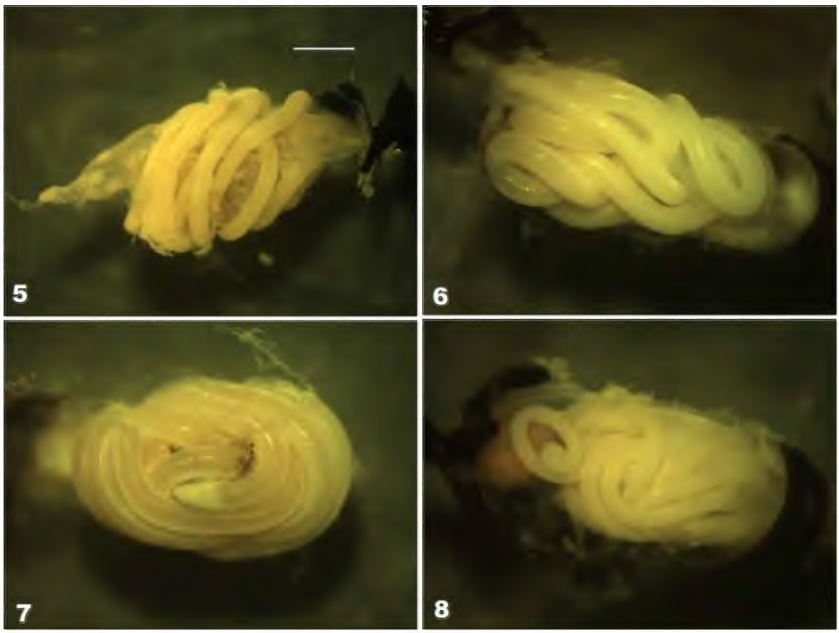
Infection rates ranged from less than 1% in a cohort of 450 *P. delecta* workers to 19% in a cohort of 21 *P monteithi* males, the latter value (and others like it) to be taken cautiously due to its small sample size. *P. delecta* carried by far the greatest infection load overall (Table 1), and might be more vulnerable to infection than some other *Polyrhachis* weaver ants (or ants in general) in the region. If so, this might offer a clue to its feeding habits. Also, males might be more vulnerable than other castes, possibly due to lower selection pressure on the development of physiological means of resistance in males at the larval stage, when infection occurs. There is evidence, in addition, that not only the phenotypic morphology of an incipient caste (Csősz and Majoros 2009) but the caste itself (Passera 1976) may be induced by mermithid infection at the larval stage, so the weighting towards males among the infected ants of this study might not indicate any propensity for infection towards male larvae. Speculation is likely to be premature, given how little is known of the biology of either the ants or the mermithids. If, for example, parasitised ants take longer to mature and/or stay in the nest longer than usual, these rates could be biased (McInnes and Tschinkel 1996, Welch 1965). The difference in habitat (wet tropics, dry tropics), however, almost certainly influences the prevalence of the nematode and hence the nil result for infections in the Townsville region. In general, levels of parasitism by mermithid nematodes are directly related to the moisture content of the habitat (Welch 1965).

In *Pheidole dentata* Mayr there can be up to 8 worms together in a single worker (Wheeler 1907), but they were always single (one only to a host) in these *Polyrhachis* ants and of two discrete sizes, presumably moult stages (Fig. 3). They occurred in males and workers of *P. delecta* (pupae and imagines) and in *P. monteithi* males. The absence of mermithids from gynes of either species was notable, especially in view of the infection rates for the other castes in the case of *P. delecta*. McInnes and Tschinkel (1996) found that mermithid parasitism is absent or very rare in gynes of *Solenopsis invicta* Buren, but common in gynes of *S. geminata* Fabricius, while O'Grady and Breen (2011) found that infection occurred in males and queens of *Lasius flavus* Fabricius but only in queens of *L. niger* Linnaeus. That is, host

selectivity appears to be a characteristic trait of mermithids and might apply not only to species but to the caste of the host species.

The mermithid from the Paluma 'giant' worker was 4-4.5 cm long (Fig. 4), the same size as Wheeler's (1907) *P. dentata* mermithids. Mermithids up to 15 cm long have been found in fire ants, *Solenopsis* Westwood sp. (McInnes and Schinkel 1996), and up to 32 cm long (*Aranimermis giganteus* Poinar and Early) in mygalomorph spiders (Poinar and Early 1990).

The nematodes occupied the haemocoels of the ants' gasters, consistent with what is known about their mode of feeding, *i.e*. by absorbing nutrients directly across the cuticle (Nickle 1972, Kaya *et al*. 1993). The host's gut with its contents passed through the centre of the worm's coils (Fig. 5) and was nowhere penetrated by them. There was no consistent pattern of coiling (Figs 6-8).



Figs 5-8. Mermithids: (5) gut of a host *P. delecta* ant within the enclosing coils of a mermithid nematode, 1 mm scale bar; (6-8) variation in the coiling of mermithid nematodes in the gasters of host *Polyrhachis* ants.

Effects on anatomical and morphological characters

Almost every infected *Polyrhachis* ant in this study appeared indistiguishable from her uninfected sisters. Modifications to appearance are nonetheless well documented, widespread, important and sometimes conspicuous effects of infection. Apart from gigantism and physogastry (enlarged gaster), a range of

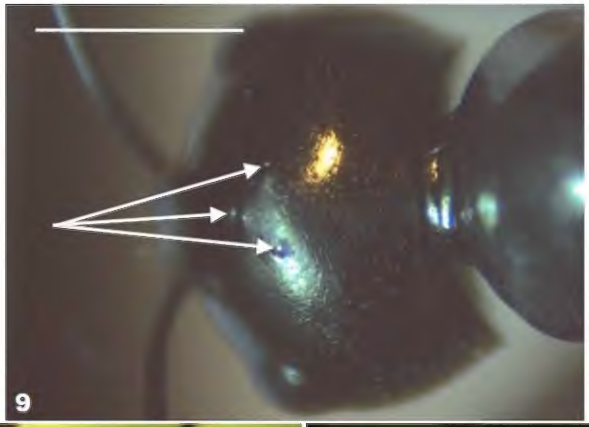
other morphological and behavioural changes, including brachyptery, intercaste features and failure to fly to a mating swarm event, have been documented as consequences of mermithid infection (Kutter 1958, McInnes and Tschinkel 1996, Wheeler 1933, O'Grady and Breen 2011, Poinar 2012, Laciny *et al*. 2017). Because gigantism, gaster distension and other morphological abnormalities can occur as a result of mermithid infection, investigators have often cited infection rates based on identifying ants that show these effects, while acknowledging that these are underestimates (Czechowski *et al*. 2007, Pérez-Lachaud and Lachaud 2014). The present results agree: neither gaster distension nor any other malformation is a necessary or sufficient condition for the presence of mermithids that fully occupy a host ant's gaster.

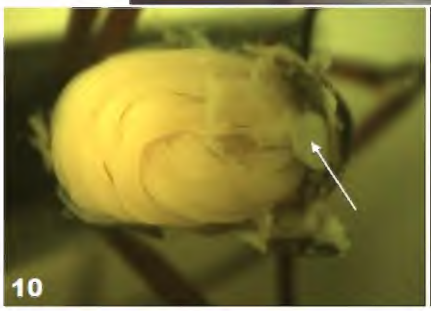
The 'giant' mermithergate *P. delecta* worker from Little Crystal Creek had head width 1.85 mm and alitrunk length 2.55, making it 32% larger than a typical uninfected nestmate, and its occiput bore three ocelli (Fig. 9). Gigantism, which along with all other morphological abnormalities must be considered uncommon to rare among *Polyrhachis* hosts if the present findings are typical, would seem to be an unlikely consequence of hosting a food-draining parasitoid. The effect, then, would seem to be one that favours the interests of the parasitoid rather than those of the host. The general understanding is that the parasitoid induces behavioural (feeding) changes in the ant larva which cause it to disregard normal hunger and satiation cues and feed unrelentingly, thus becoming larger than normal and providing more body space for the subsequent growth of the nematode. Exactly how this excess solicitation occurs remains unresolved, but the scarcity of gigantism in this study and others suggests that gigantism is a non-functional side effect, relatively rarely triggered by infection, rather than an evolved mechanism serving the developmental needs of the mermithid. This view is supported by the sizes of the worms from this study: the mermithid in the 'giant' was no larger than those in normal-sized workers.

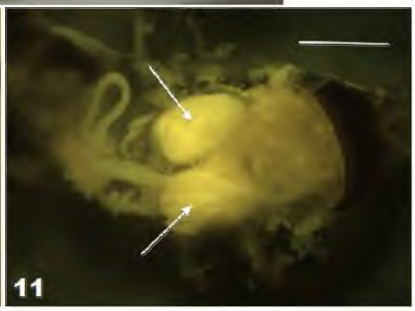
The *Polyrhachis* size data from the present study (Table 2) were expected to confirm the visual impression, that large, late-stage juvenile mermithids almost invariably occured in ants of normal size and form. Unexpected, to say the least, was evidence that the hosts were significantly smaller on average than their siblings for 3 out of 4 characters measured (Table 2). This result contrasts with size comparisons made between infected and uninfected individuals in black flies and weevils, where parasitised hosts were larger (Strickland 1911, Poinar and Gyrisco 1962, Welch 1965), but is consistent with studies showing that gigantism is neither universal nor obligatory in affected ants (Wheeler 1907, 1929, Gösswald 1930, Vandel 1930, Kloft 1949, 1950, Crofton 1966, Poinar 2012).

The presence of a mermithid appeared not to adversely affect the host's gut (Fig. 5) or (in workers) the poison gland (Fig. 10) or (in males) the

reproductive system (Fig. 11) in any of the *Polyrhachis* hosts treated here. All structures were retained and presumably functioned normally. In particular, the normal pattern of gonad maturation and decline in males, *i.e.* pre- and post-mating changes to the testes, appeared uncompromised: gonads were maximally developed in male pupae and young (paler) males and showed increasing degrees of atrophy in older (darker) males. This is in contrast to the reported complete loss of the fat body and reproductive organs in *Pheidole commutata* Mayr (Wheeler 1907) and, in general, the expectation that internal parasitoids of the size of mermithids will seriously damage the organs (Welch 1965). Perhaps this explains the apparently disproportional infection rates among males: males are not compromised by infection – it doesn't stop them mating, after which they die quickly. Hence they need no protection and thus carry the heaviest infection load.







Figs 9-11. Ocelli, poison gland and gonads of mermithid-infested *Polyrhachis* ants: (9) ocelli (arrowed) on the occiput of mermithergate *P. delecta* worker #155, scale bar 1 mm; (10) poison gland (arrowed) of normal appearance and (presumably) function, in the posterior part of the gaster of a mermithid-infected *Polyrhachis* worker; (11) *Polyrhachis* male gonads (arrowed) unaffected by the presence of a mermithid nematode, dorsal aspect, 1 mm scale bar.

Table 2. Size comparisons (mm) between *P. delecta* ants infected and uninfected by mermithid nematodes. AL: alitrunk length. HW: head width.

Species	caste	status	character	mean	sd	t, df, p	n
delecta	w	infected	AL	1.83	0.07	0.63, 25, 0.29	7
		uninfected	AL	1.85	0.07		20
		infected	HW	1.39	0.02	5.00, 25, <<0.001	7
		uninfected	HW	1.48	0.07		20
	m	infected	AL	2.47	0.07	4.18, 80, <<0.001	32
		uninfected	AL	2.53	0.05		50
		infected	HW	1.04	0.04	4.39, 80, <<0.001	32
		uninfected	HW	1.07	0.03		50

Early juvenile stages

Dissections of *P. delecta* pupae from Mission Beach yielded 5 early-stage juvenile mermithids, 4 from males and one from a worker (Fig. 12). Like those infecting imagines, these were located in the haemocoel, around the midgut. Their lengths were about 3-3.5 mm (Fig. 13). This is consistent with expectations based on what is known about the life cycle of these nematodes and were the same size as larval mermithids found in workers of the fire ant S. *geminata* from Florida (Mitchell and Jouvenaz 1985).

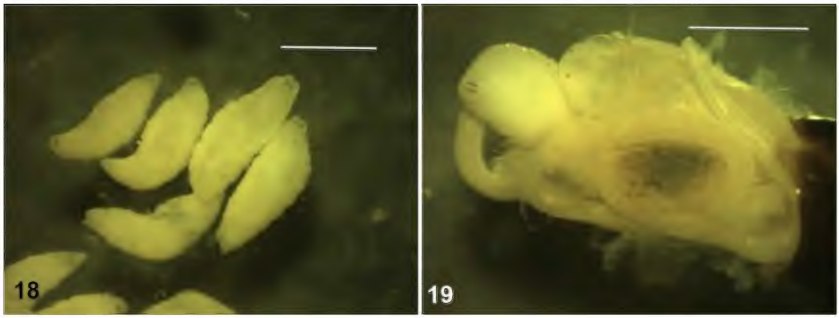
There are 6-8 known types of life cycle in the family Mermithidae (Nickle and Welch 1984) but it has been completely determined in just a few cases (Bedding 1984)]. However, for the seven genera of mermithids known to be ant parasitoids, all of the hosts feed infected earthworm, caddis fly or other animal prey to their larval siblings, consistent with an indirect life cycle involving a paratenic host (Nickle and Welch 1984, Poinar 2012). Because the terrestrial intermediate (paratenic) host occurs in a habitat wetter than that of the final (developmental) host (Poinar 2012), it might be expected that arboreal weaver ants would be less vulnerable to infection than soil-dwelling ants, so the same indirect cycle, however likely, must remain for the time being unconfirmed for *P. delecta* and other arboreal ants of the genus *Polyrhachis*. It seems logical, however, to expect at least in part a carnivorous diet for ants found to host mermithids, on the basis of what is known about other ants subject to infection.

Figs 12-17. Parasitised *Polyrhachis* spp: (12) early juvenile mermithid nematode in the gaster of a male *P. delecta* ant, 1 mm scale bar; (13) size of an early juvenile, 2 mm background grid; (14-17): multiparasitism in males of *Polyrhachis delecta* (14-15) and *P. monteithi* (16-17) by a mermithid nematode and the larvae of an insect parasitoid – the larvae are packed dorsally, the nematode is entirely ventral: (14, 16) before dissection; (15, 17) with some gastral sclerites removed.

Multiparasitism

There were six cases (four *P. delecta* males and two *P monteithi* males) of multiparasitism, *i.e.* when the mermithid was sharing the host with the larvae of an insect parasitoid, and in those circumstances the gaster was always distended (Figs 14-17). The larvae were clumped above (dorsal to) the mermithid and were lightly encased in a membranous shroud of their own.

A separate overall shroud of similar appearance enveloped larvae and nematode jointly, while the nematode retained its own flimsy shroud. These parasitoid larvae (Figs 18-19) were found independently (*i.e.* without mermithids) in 59 other ants of three species (Table 3), including three in *P. delecta* pupae.



Figs 18-19. Larvae of an insect parasitoid infecting *Polyrhachis delecta* males: (18) typically-sized larvae, 1 mm scale bar; (19) two large larvae and a mermithid nematode together in the gaster of the same host ant, 1 mm scale bar.

Table 3. Cases of infection by an insect parasitoid in 3 species of *Polyrhachis* ants. Numbers of larvae per host ant given as mean ± standard deviation or as individual scores for n<3.

Species	caste	mean ± sd	n
delecta	gyne	20.7 ± 6.3	6
	male	19.9 ± 7.0	22
	worker	15.4 ± 9.4	14
	pupa (w)	19.0 ± 5.3	3
monteithi	gyne	39	1
	male	24.3 ± 11.9	3
	worker	24.0 ± 11.6	8
queenslandica	worker	18,19	2

Only one other instance of multiparasitism (Welch 1965, Quicke 1997) is known in ants: *Ectatomma tuberculatum* (Olivier) parasitised by the chalcidoids *Dilocantha lachaudii* Heraty and *Isomerala coronata* (Westwood) simultaneously (Perez-Lachaud *et al* 2006, 2010) and, in this case the two parasitoids were relatively closely related (both were wasps). The joint occurrence of nematid and insect parasitoids seems to be unique. Also, the presence of the parasitoid larvae in the pupae of the host ants indicated that the original infection was very likely at the larval stage, as was the case in the endoparasitoid infection of *Ectatomma ruidum* (Roger) by a

presumed phorid fly (Lachaud and Pérez-Lachaud 2015). There is evidence that multiple natural enemies may act synergystically, making a host more prone to infection by others (Dogiel 1964, Jouvenaz 1983).

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A NEW NAME FOR THE AUSTRALIAN DUNG BEETLE *ONTHOPHAGUS BICORNIS* MACLEAY, 1888 (COLEOPTERA: SCARABAEIDAE), WITH NOTES ON TYPE LOCALITY, DISTRIBUTION AND BIOLOGY

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Abstract

A new name, *Onthophagus froggattellus* Monteith & Rossini, **nom. nov.** is proposed for the preoccupied *Onthophagus bicornis* Macleay, 1888 and its type specimens and type locality near King Sound, NW Australia, are clarified. It occurs in a number of disjunct distributional foci across tropical Australia and specialises on dung of the fungus-feeding northern bettong, *Bettongia tropica* Wakefield, in part of its range.

Introduction

In 1887, the wealthy Sydney patron of natural history, William John Macleay, engaged the 28 years old Walter Wilson Froggatt to go for a year to the newly settled town of Derby, at the foot of King Sound on the remote NW Kimberley Coast of Australia, to collect specimens for his private Macleay Museum. Froggatt was an experienced and bold collector who had already been on the Royal Geographical Society of Australasia (NSW) 1885 New Guinea Expedition (Fig. 1) and had been employed previously by Macleay to collect in north Queensland in 1886 (Froggatt 1935). Froggatt was at King Sound from April 14, 1887 to February 22, 1888 (Froggatt 1934). Macleay exhibited some of Froggatt's advance collection at meetings of the Linnean Society of NSW in late 1887 before Froggatt himself returned to Sydney (Macleay 1888a). Soon after Froggatt's return, Macleay published a paper, in 3 parts, entitled 'The Insects of King's Sound and its vicinity', describing 183 new species of Coleoptera from the material (Macleay 1888b, c, d), including 17 dung beetles. One of these, described on p. 901 of the second part, is a small brown dung beetle he called *Onthophagus bicornis* Macleay, 1888. As with all the species in these papers, he made no mention of particular specimens and did not designate types in the text, but his description of *O. bicornis* makes it clear that he had at least one male and one female before him.

William Macleay, at that time, was elderly and in poor health. The curating and labelling of his specimens would have been done by George Masters, an experienced entomologist whom Macleay had lured from employment at the Australian Museum in 1874 to be curator of his private museum. In the same year that he published on those King Sound collections (1888), Macleay gifted his whole private museum to the University of Sydney and gave funds for it to employ George Masters to curate the collection until Masters' death (Strahan 1979). Macleay died three years later and George Masters lived until

1912. Due to inadequate funds, the collections of the Macleay Museum progressively declined after Masters' death. In 1962, the then curator Elizabeth Hahn published a list of the designated insect types in the Macleay Museum but there were no entries for any of the 17 species of dung beetles described by Macleay from Froggatt's King Sound collections (Hahn 1962). In 1969 an agreement was reached to transfer all recognisable insect types and other important specimens in the Macleay Museum on permanent loan to the Australian National Insect Collection, where the material was to be restored and catalogued (Upton 1997). This included more than 5000 insect specimens, of which Britton and Stanbury (1982) lised the Coleoptera types so transferred and these included '2S' [two syntypes] of *Onthophagus bicornis* from 'King Sound, WA'.

As another, long-forgotten and earlier American species with the same name as this Australian dung beetle has been recently revealed, a new specific epithet is required for the latter. We take the opportunity to review the types and type locality of the Australian species and to summarise what we know today of its distribution and biology.

Fig. 1. Walter Wilson Froggatt (1868-1927) centre, with 3 of the 11 fellow members of the Royal Geographical Society of Australasia (NSW) 1885 New Guinea Exploring Expedition. The others are S.A. Bernays (right), W. Bäuerlen (lower left) and G.E. Hemsworth. Detail from an original photograph in Queensland Museum taken in Sydney on 3 December 1885, the day the expedition arrived back in Sydney.

Museum collection abbreviations

AM – Australian Museum, Sydney (Derek Smith); ANIC – Australian National Insect Collection, Canberra (Cate Lemann); MNHN – Muséum National d'Histoire Naturelle, Paris; NTDPI – Northern Territory Department of Primary Industries, Darwin; QDAF – Queensland Dept. of Agriculture and Forestry, Brisbane (Justin Bartlett); QM – Queensland Museum, Brisbane.

Taxonomy and nomenclature

Matthews (1972) revised the Australian *Onthophagus* and included *O. bicornis* Macleay in his *erichsoni*-group, which comprises 6 comparatively rare species, all confined to the tropical north of the continent and of which *O. bicornis* Macleay is the smallest (*ca* 8 mm) (Figs 2-3). A recent paper by Rossini *et al.* (2016) has revealed another species named *Onthophagus bicornis* Laporte (= Castelnau), 1840. In their review of the three African *Onthophagus* species belonging to 'Group 27' of d'Orbigny (1913), they found that all three were based on mislabelled American specimens and that one of them, *viz*. *O. semichalcites* d'Orbigny, 1902, is a junior synonym of the American *Onthophagus bidentatus* Drapiez, 1819. Further, they showed that the overlooked species *O. bicornis* had been described by Laporte (1840) on the same type material as used by Drapiez (1819) to describe *O. bidentatus.* They located one specimen in the MNHN (labelled 'Cayen.' = Cayenne, French Guiana) from the original series that formed the basis of descriptions of both *O. bidentatus* and *O. bicornis* and designated it as the lectotype of both species (Rossini *et al.* 2016), an action permitted under Article 72.6 of the ICZN (1999).

Figs 2-3. *Onthophagus froggattellus* Monteith & Rossini, *nom. nov.*, oblique views: (2) male (Koongarra, NT); (3) female (Koongarra, NT). QM registration numbers of specimens shown. Photos by G. Thompson, Queensland Museum.

Onthophagus bicornis Laporte has been regarded as a junior synonym of *O. bidentatus* since at least the catalogue of Blackwelder (1944). This overlooked name is thus a senior homonym of the Australian *Onthophagus bicornis* Macleay, 1888, necessitating a new specific name for the latter.

Therefore, we propose the name *Onthophagus froggattellus* Monteith & Rossini, **nom. nov** for the Australian taxon under the provisions of Article 52.1 of the ICZN (1999). The name honours Walter Froggatt, whose pioneering fieldwork discovered the species, while the diminutive ending of '*-ellus*' refers to its small size within the *erichsoni*-group. Macleay described *Onthophagus froggatti* Macleay, 1887 in Froggatt's honour for a north Queensland species but that name is now a synonym of *Onthophagus furcaticeps* Masters, 1886 (Blackburn 1903).

Status of Type specimens

The two syntypes of *O. bicornis* Macleay listed by Britton and Stanbury (1982) were examined by GBM at ANIC in April 2017. They comprised a male (left) and a female in good condition glued ventral side down on white card and had the following labels (Fig. 4) (labels separated by /): N.W.Aust. (printed, white)/ *Onthophagus bicornis*, Macl. Barrior Range, N.W.Aust. (handwritten on white in style of George Masters)/ Syntype (printed, red)/ On permanent loan from MACLEAY MUSEUM, University of Sydney (printed, white)/ ANIC Database No 25 024046 (printed, white).

Fig. 4. *Onthophagus froggattellus,* original labels of the lectotype and paralectotype. Label 1 is the original label found on most of Froggatt's 1887 NW Australia insects, 2 is the label placed by Masters or Macleay at the time of description *ca* 1887/8, 3 and 4 are the labels placed at time of transfer to ANIC in 1969-70, and 5 is ANIC's much later database registration label. Lectotype, paralectotype and *nom. nov.* labels are now added. Photos by Cate Lemann, ANIC.

Matthews (1972), in his monograph of Australian *Onthophagus*, listed the type of *O. bicornis* as: 'Holotype ♂, King's Sound, W.A., MM. Seen by the author.' but did not attach any type label. Cassis and Weir (1992), in their catalogue of Australian Scarabaeoidea, interpreted Matthew's incorrect inference of a holotype as being a lectotype designation and they referred to three specimens: 'lectotype ♂*' and 'paralectotypes ♂♀'. Their asterisk (*) indicates that they did not examine the types in taking this action under Article 74 of the 1985 ICZN (Explanatory Note 9 on p. ix of Houston 1992 and second paragraph on p. 107 of Cassis and Weir 1992).

The Australian Faunal Directory (2017) followed Cassis and Weir and listed a ♂ lectotype and ♂♀ paralectotypes. The assertion that there are 3 and not 2 type specimens is a *lapsus*. Both Britton and Stanbury (1982) and the CSIRO database record for Reg. No. 25 024046 (CSIRO 2017) reported only the two specimens currently present. The specimens had no indication of their current lectotype status so the following three labels were added by GBM: Lectotype ♂, *Onthophagus bicornis* Macleay 1888 (handwritten on red)/ Paralectotype ♀, *Onthophagus bicornis* Macleay 1888 (handwritten on red)/ *Onthophagus froggattellus* Monteith and Rossini 2017, n. name for preocc. *bicornis* (handwritten on white).

Tom Weir (pers. comm.) located three additional females in the Macleay Museum, all labelled 'N.W. Aust' and now in ANIC. They do not bear original identification labels. These specimens might have been seen by Macleay but, since they were not seen and/or recognised as part of the type series by Hahn (1962), Britton and Stanbury (1982) or Matthews (1972), it does not seem appropriate or useful to consider them as paralectotypes now.

Clarification of Type locality

The only locality information given by Macleay for the species he described from Froggatt's NW Australia material is 'vicinity of Derby, Kings Sound' and 'limited to a few miles around Derby' in Macleay (1888a) and 'King's Sound and its vicinity' and 'King's Sound district' in Macleay (1888b). The exception was that on p. 446 of Macleay (1888b), where he stated that two tiger beetles were from 'upwards of 100 miles inland from the King's Sound, in the neighbourhood of the Barrier Range'.

The modern treatments (Matthews 1972, Cassis and Weir 1992) listed the type locality of *O. bicornis* as 'King's Sound' and 'King Sound' respectively. However, the original label on the types (see above and Fig. 4), probably attributable to George Masters, reads 'Barrior Range, N.W. Aust' and the CSIRO Database for the specimens follows this but corrects the spelling to 'Barrier Range'. It has been overlooked that Froggatt, towards the end of his life, published a very detailed account of his 1887 King Sound expedition (Froggatt 1934). After arriving in Derby on 14 April 1887, he camped for 5 weeks outside the town then 'at a police auction I bought a spring cart, a horse, and harness and packed up, leaving my Derby camp on May 21'. Alone, he drove his spring cart for 150 km over 12 days, passing Butler's Lake and Mt Marmion, then following the Lennard River to a place where it cut a deep gorge, which he called 'Devil's Pass', through a '200 feet high' vertical-faced limestone range he called the 'Barrier Range'. He camped there for two and a half months near the homestead of the King Sound Pastoral Company and returned to the same place for another two months during the December-February wet season. This was the major locality of his year-long stay at King Sound and is recorded as 'Barrior Range' on many of his specimens. Barrier Range and Devil's Pass do not appear on maps today

but have been replaced by the modern names of Napier Range and Windjana Gorge, the former a famous Devonian fossil site and the latter a popular tourist site. We can therefore confidently ascribe the type locality of *Onthophagus froggattellus* and other 'Barrier Range' species described by Macleay as the vicinity of Windjana Gorge (Fig. 5, Table 1).

Geographical distribution of *Onthophagus froggattellus*

There are few published records of *O. froggattellus* since its description but they show a remarkable spread across the tropical north of Australia. Blackburn (1903) mentioned seeing specimens from Northern Territory without further details. Matthews (1972) said the species was 'apparently rare' and listed specimens from near Paluma in Queensland and from Groote Island in NT, both far from the type locality. Weir (1993) recorded it from Heathlands Nat. Park in Cape York Peninsula. Vernes *et al.* (2005) recorded 21 specimens collected during two years' mammal trapping at Davies Creek, near Cairns, N. Queensland.

There has been widespread collecting of dung beetles across the north of Australia over the last 50 years by entomologists from ANIC, QM, DAF and NTDPI, resulting in hundreds of thousands of specimens having been processed. Survey of collections and literature for this paper revealed records for 94 specimens of *O. froggattellus* collected on 54 different occasions since Froggatt collected the first specimens. Of these, 22 localities were specified accurately enough to be mapped (Fig. 5, Table 1).

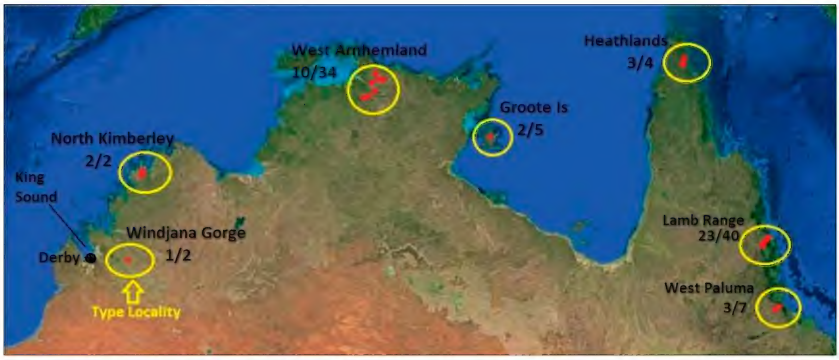

Fig. 5. Distribution map of *Onthophagus froggattellus*. Latitudes, longitudes and altitudes for the points are given in Table 1. Yellow circles highlight the discrete distribution foci of the species. Figures show the number of records and total specimens within each circled region. Base map from Google Earth.

This revealed a strikingly disjunct series of collecting foci (yellow circles on Fig. 5), which seems to be a genuine reflection of the species' range. All of these foci are comparatively remote places that have yielded repeated

Table 1. List of localities for *Onthophagus froggattellus*, drawn from specimens and literature records that are accurate enough for mapping and contribute to the points in Fig. 5.

Distribution foci	Locality	Longitude	Latitude	Altitude	Source
WINDJANA	Windjana Gorge	124.941°E	17.418°S	100m	ANIC
NTH KIMBERLEY	8km SW of Walsh Point	125.800°E	14.616°S	280m	ANIC
NTH KIMBERLEY	Boab Camp, Mitchell Plat.	125.825°E	14.790°S	330m	ANIC
W. ARNHEMLAND	11km S by W Nimbuwah	133.333°E	12.285°S	70m	QM
W. ARNHEMLAND	Koongarra 1	132.821°E	12.877°S	20m	ANIC
W. ARNHEMLAND	Koongarra 2	132.876°E	12.873°S	25m	QM
W. ARNHEMLAND	Nourlangie Creek	132.726°E	12.804°S	15m	ANIC
W. ARNHEMLAND	Cahill's Crossing	132.965°E	12.427°S	15m	ANIC
W. ARNHEMLAND	Cooper Creek	133.066°E	12.099°S	30m	NTDPI
W. ARNHEMLAND	Birraduk Creek	133.216°E	12.266°S	55m	NTDPI
GROOTE ISLAND	12km N of Central Hill	136.640°E	13.856°S	30m	QM
HEATHLANDS	7km NE of 3-ways Junct.	142.732°E	11.645°S	120m	AM
HEATHLANDS	Heathlands NP HQ	142.586°E	11.752°S	110m	ANIC
LAMB RANGE	Davies Creek 1	145.590°E	17.025°S	670m	ANIC
LAMB RANGE	Davies Creek 2	145.580°E	17.015°S	660m	ANIC
LAMB RANGE	Davies Creek 3	145.608°E	17.030°S	720m	QM & QDAF
LAMB RANGE	Davies Creek 4	145.589°E	17.026°S	550m	Vernes *et al.*
LAMB RANGE	Tinaroo Ck. Road	145.537°E	17.110°S	770m	QDAF
LAMB RANGE	Emu Creek	145.541°E	17.106°S	850m	ANIC
LAMB RANGE	7km NE of Tolga	145.485°E	17.150°S	620m	QDAF
WEST PALUMA	9 ml W of Paluma	146.072°E	19.019°S	800m	ANIC
WEST PALUMA	11 ml W of Paluma	146.067°E	18.997°S	770m	ANIC

collections of this species, while better collected intervening areas have yielded none. All habitats are open forest, with a single specimen from Davies Creek labelled as 'rainforest'. The habitats at the Lamb Range and West Paluma foci are both of moderate altitude (550-850 m) with tall moist open forest on granite soils in the rain shadow of rainforested mountains. All other sites are very different, with low altitude (max. 280 m), long monsoonal dry seasons, sandy soil and with vegetation being heaths or low woodlands.

Biology of *Onthophagus froggattellus*

Several groups of *Onthophagus* dung beetles in Australia utilise decaying mushroom material in preference to dung as food and/or brood material. Matthews (1972) summarised what was then known, listing 10 species, in 5 different species groups, that regularly used mushrooms. All six species of the *erichsoni*-group (to which *O. froggattellus* belongs) were then regarded as rare in collections and none was cited by Matthews as a mushroom specialist. Since then, decayed mushroom, as well as dung, has been regularly used as bait in survey collecting of Australian dung beetles. Storey and Weir (1988) first noted that one of the *erichsoni*-group species (*O. capellinus* Frey, 1963) was a mushroom specialist. Weir (1993) noted that *O. wigmungan* Matthews, 1972 is also fungus associated and we now know (GBM pers. obs.) that *O. tabellicornis* Macleay, 1864, *O. erichsoni* Hope, 1841 and *O. picipennis* Hope, 1841 also prefer mushroom baits.

Thus, *O. froggattellus* is the only species of the *erichsoni*-group not yet shown to be mycophagous. Of the 54 collection events of *O. froggattellus* reviewed for this study, 30 recorded the collection method. Of these, 16 were taken at light traps and two were from pitfalls baited with human excrement. The remaining 12 events were associated with small macropod marsupials known as bettongs (Potoroidae) and all took place in the Lamb Range area (Fig. 5). In a study by Vernes *et al.* (2005) at Davies Creek, small ground mammals were trapped in cages with mesh floors, recorded and released, for two years in 9 quadrats spread over two vegetation types. Dung beetles were collected from the dung deposited under traps and the species of mammals recorded. Five species of mammals were trapped (1104 individuals) and 11 species of dung beetles were collected (541 individuals).

Whereas most dung beetles were associated with two or more mammals, every specimen of *O. froggattellus* (21 specimens on 11 occasions) was taken from dung of the northern bettong (*Bettongia tropica* Wakefield, 1967), which has a very small distribution confined to three separate restricted populations in North Queensland (Claridge *et al.* 2007), two of which coincide precisely with the Lamb Range and West Paluma populations of *O. froggattellus* (Fig. 5). The range of the third northern bettong population (Windsor Tableland) is in similar habitat to the Lamb Range and West Paluma populations but has not been well sampled and *O. froggattellus* might well be there.

Another puzzling bettong record refers to a male and female of *O. froggattellus* in ANIC labelled: 'Emu Creek, Lamb Range, N. Qld, 23.i.94, A.L. McIlwee, ex fur at anus of brushtail bettong'. There are *Onthophagus* species in Australia with specialised claws that enable them to cling to fur at the anus of macropods (Matthews 1972) but *O. froggattellus* is not one of them and the specimens from Emu Creek might have been taken in confined circumstances on a trapped animal with dung present. The brushtail bettong is the common name given to *Aepyprymnus rufescens* (Gray, 1837). Wright (1997) carried out an intensive year-long study of dung beetles associated with this bettong species and its habitat at Mt Fox, 30 km north of the West Paluma centre. She found that this mammal is highly associated with one of the prehensile dung beetles, *O. peramelinus* Lea, 1923 and did not record *O. froggattellus* among the 40 dung beetle species in her study area, which also does not have *Bettongia tropica*.

Bettongs are partly mycophagous, feeding on both subterranean and above-ground mushroom-type fungal fruiting bodies (Claridge *et al.* 2007) and *B. tropica* is almost exclusively so. They have specialised digestive systems involving fermentation to deal with the fungal diet and this presumably produces dung of different quality to that of herbivores. It is difficult not to speculate that there is an evolutionary link between the fact that *O. froggattellus* belongs to a species group of otherwise mushroom-feeding dung beetles and its specialisation on the dung of a mushroom-feeding mammal. However, while northern bettongs are common at both the Paluma West and Lamb Range, all the other populations of *O. froggattellus* shown on Fig. 5 have different lowland habitats and are beyond the present and past range of any species of fungal-feeding bettongs (Claridge *et al.* 2007). So, what does *O. froggattellus* feed on in these other places?

IUCN listing

Onthophagus froggattellus is included (as *O. bicornis* Macleay) in the International Union for Conservation of Nature Red Data list as a rare species in the category of 'least concern' (IUCN 2008).

Acknowledgements

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A NOTE ON THE FEMALE OF *PLATENSINA PARVIPUNCTA* MALLOCH (DIPTERA: TEPHRITIDAE: TEPHRITINAE)

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Abstract

The female of *Platensina parvipuncta* Malloch, known previously only from the holotype male collected in Cairns, northern Queensland, is newly recorded from Carnarvon Station, central Queensland.

Introduction

Australian species of *Platensina* Enderlein were revised by Hardy and Drew (1996) and reviewed by Hancock (2012), who both recorded four species: *P. parvipuncta* Malloch, *P. platyptera* Hendel [as *P. amplipennis* (Walker) in Hardy and Drew 1996], *P. trimaculata* Hardy & Drew and *P. zodiacalis* (Bezzi). Hancock (2013) added a fifth, *P. ampla* de Meijere. Until now, *P. parvipuncta* has been known only from the holotype male collected in Cairns, northern Queensland (Hardy and Drew 1996).

Female of *Platensina parvipuncta*

The female recorded here bears the following data: Qld: 24.831ºS x 147.742ºE, Carnarvon Stn, nr Piebald Spring (CN1M1), 13.xii.2010-15.vi.2011, 821 m, C. Zwick, C. Wilson, Malaise, *Euc./Callistemon* rocky gully, 19428 (in Queensland Museum, Brisbane).

The female resembles the male (see Fig. 167 In Hardy and Drew 1996) except that the wing has the broad hyaline indentation in cell r_1 just beyond the stigma divided into three spots, one elongate basal indentation from costa across cell r_1 into cell r_{2+3} and two small round spots just beyond it in cell r_1; the small hyaline preapical spot in cell r_1 is present as in the male. Cell dm has a small hyaline spot placed centrally just basal to the line of R-M crossvein and cell cu_1 has an additional hyaline spot anteriorly between the spot in cell dm and two small marginal indentations; the distal marginal indentation is elongate and almost reaches vein Cu_1. The crescentic hyaline apex from middle of cell r_{2+3} to upper part of cell m and the two small hyaline indentations in posterior half of cell m are as in the male.

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A CHROMOSOME STUDY OF FOUR AUSTRALIAN SPECIES OF SPIDERS OF THE GENUS *CORASOIDES* (ARANEAE: DESIDAE)

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Abstract

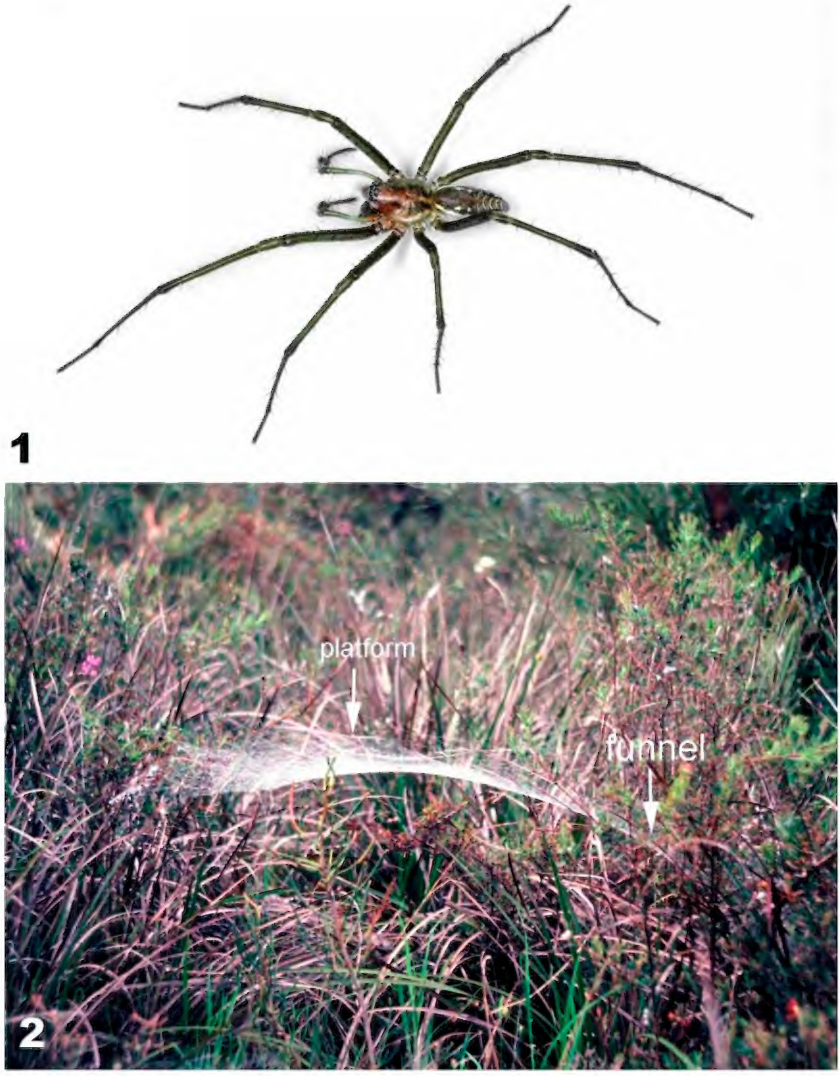
Spreads of meiotic and mitotic cells were used to investigate cytogenetics of some spiders of the genus *Corasoides* Butler (family Desidae), namely *C. australis* Butler, 1929, *C. mouldsi* Humphrey, 2017, *C. occidentalis* Humphrey, 2017 and *C. terania* Humphrey, 2017. All four species were found to have 2N=46 + $X_1X_2X_3$ for males and 2N=46 + $X_1X_1X_2X_2X_3X_3$ for females. Most species could be distinguished by the relative lengths of their X chromosomes.

Introduction

Spiders of the genus *Corasoides* Butler, 1929 are common, medium-sized spiders (Fig. 1), in the family Desidae, which belong to the entelegyne lineage of araneomorph spiders. Members of this genus make horizontal platform webs arising from a retreat (Fig. 2). This retreat is either a burrow dug in the ground in dry habitats or a ready-made retreat in a tree trunk or debris in rainforest. The genus has nine species occurring in eastern, southern and southwestern Australia and the highlands of Papua New Guinea (Humphrey 2017). This study examines and compares the male and female chromosomes of four species, namely *C. australis* Butler, 1929, *C. terania* Humphrey, 2017, *C. mouldsi* Humphrey, 2017 and *C. occidentalis* Humphrey, 2017.

Although spider chromosomes have been studied from the beginning of the last century (Wallace 1905, Painter 1914, Warren 1926), their cytogenetics is still not satisfactorily understood, although the diploid number and sex chromosome system for many species have been recorded. Araujo *et al.* (2012) reviewed the behaviour of sex chromosomes in spiders but the cytogenetics of many families is still unknown. Most entelegyne spiders exhibit unusual multiple X chromosome systems. During male meiosis the X chromosomes show greater condensation and hence are darker staining. They also condense and segregate earlier than the autosomes, doing so as a single unit and often can be seen closely aligned during prophase I following a centromeric association (Rowell 1991a). Benavente and Wettstein (1977) and Wise (1983) reported the presence of a so-called junction lamina, similar in appearance to a synaptonemal complex, between X chromosomes of male wolf spiders. White (1973) reported that 81% of spider species are XX and that this condition is considered ancestral to XXX. Kral *et al.* (2006) found diverse karyoytpes in basal clades of araneomorphs and suggested that the most probable ancestral, male, entelegyne karyotype is 2N = 42 (X_1X_2). Kral *et al.* (2013) reported that X_1X_2 systems are uncommon in mygalomorphs. Korinkova and Kral (2013) suggested that the most plausible origin of the X_1X_2 system was from duplication of an X chromosome and that the $X_1X_2X_3$ system was formed by chromosome duplication. Fusions of autosomes and

sex chromosomes have been reported by Maddison (1982), Rowell (1985, 1990, 1991a, 1991b), Sharp and Rowell (2007) and Kral *et al.* (2006, 2011, 2013).



Figs 1-2. *Corasoides occidentalis*: (1) male, Ioppolo Nature Reserve, WA; (2) web, Yallingup, WA.

Methods

Meiotic and mitotic cells were extracted from male testicular tissue and mitotic cells from embryonic tissue. Live specimens of *C. australis* were collected from Fraser Island and Blackdown Tablelands (Qld), Sydney (NSW), Morgan, Wipena Pound, Port Lincoln, Streaky Bay and Nullarbor (SA) and Coolgardie and Collie (WA); *C. mouldsi* from Windsor Tableland (Qld); *C. occidentalis* from Stokes River National Park, Fitzgerald River National Park, Corrigin, Gelorup, Glen Forrest, Nannup, Stirling Ranges, Cervantes and near Jewel Cave, WA and *C. terania* from Terania Creek, Mt Nardi National Park and Border Ranges National Park, NSW.

Penultimate males were used preferentially for testicular tissue as these provided a greater proportion of cells undergoing meiotic division. Slides prepared from adult males also had ample meiotically dividing cells but usually had large numbers of spermatozoa, which often ruined otherwise useable spreads. Whenever possible, five specimens of each species were used and results determined separately to allow detection of aberrant specimens.

Live specimens were anaesthetised with carbon dioxide and the testes removed in insect saline. Since different regions of testes can differ by ratio of particular meiotic stages, samples were taken from various sections of the testes. These were soaked for 3-10 minutes in a hypotonic solution of 1:2 Ringer's insect saline:water to spread the chromosomes. They were then fixed by pipetting off the saline solution and replacing it after several washes of a mixture of 1:3 methanol and glacial acetic acid with a fresh mixture of the latter for 1-1.5 hours. Pieces of fixed testis were then placed on pre-washed microscope slides and tapped out with the flat end of a small brass rod to produce a cell suspension. This suspension was spread over the slide by alternatively tilting and partially drying the cell suspension over a warming tray. After 24 hours the slide was stained with 5% Giemsa in phosphate buffer.

The concentration of the hypotonic solution in which the tissue was soaked was altered from 1:3 or even 1:4 insect saline:water when resulting chromosomes were poorly spread. If the chromosome spreading was unsatisfactory, new tissue was soaked for longer, up to 15 minutes, and the tissue was torn into smaller pieces. Suitable spreads were photographed using a light microscope with an oil immersion lens and chromosome pairs counted from the prints.

Chromosome counts of 20 cells were taken or as many more as needed to reliably establish the chromosome number. Some mitotic cells from the testicular tissue were also examined and used for confirmation of results.

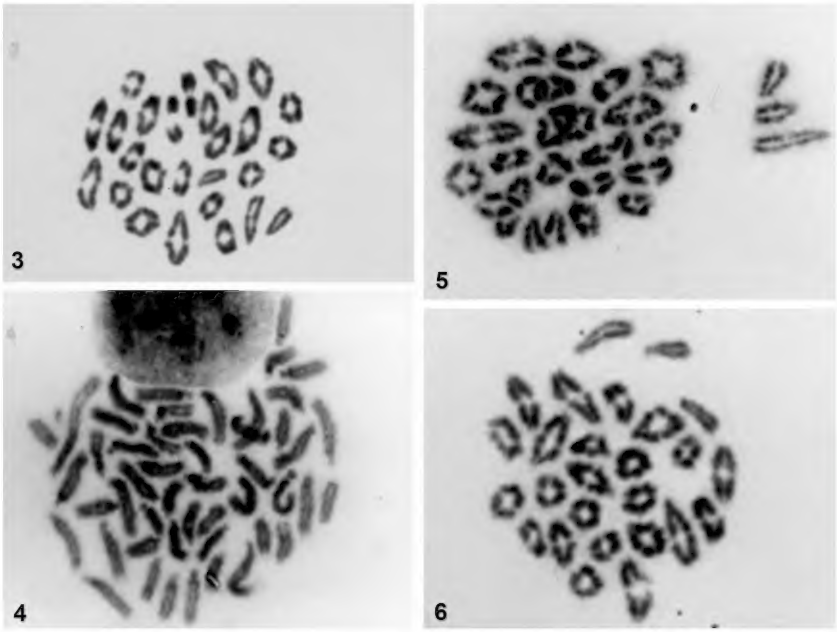
Embryonic cells of *C. australis* were also prepared in order to observe mitotic cells in both sexes and confirm the 2N for females and the method of sex

determination. Embryos used had reached the stage where they had formed limbs but eyes had not pigmented nor spines formed. Yolks were carefully removed to avoid contamination by fat globules. Whole embryos were fixed, spread and stained by the same method as testicular tissue.

Results and discussion

All species of *Corasoides* examined cytogenetically had a karyotype of 23 pairs of autosomes and three X chromosomes, *i.e.* 2N = 49 for males.

Most of the autosomes appeared either telocentric or acrocentric but it was often difficult to determine the centromere position. The three sex chromosomes were unequal in length and often observed together on the periphery of the nucleus. They were generally darker staining than the autosomes and condensed, aggregated and segregated earlier than the autosomes.



Figs 3-6. *Corasoides terania*, male, specimens from Terania Creek, NSW: (3) Metaphase I, spread showing 23 pairs of autosomes and three X chromosomes, one long and two short; (4) Mitotoic metaphase. Several chromosomes appear either acrocentric or with satellites; (5-6) Metaphase I, showing 23 pairs of autosomes and three X chromosomes at the periphery of the plate. The chromatids of the longest sex chromosomes are slightly uneven in length and show a thinning of chromatin midway.

Corasoides terania (Figs 3-6)

Chromosomes spreads were examined from specimens from Terania Creek, Mt Nardi and Border Ranges National Park, NSW. Meiotic spreads showed 23 pairs of autosomes plus three X chromosomes *i.e.* 2N = 49 in the male. These preparations suggested that all autosomes are telocentric but resolution was poor and photographs of mitotic cells (Fig. 4) show at least eight pairs are either acrocentric or possess a satellite. There is one long and two shorter sex chromosomes, the latter roughly equal in length (Figs 3, 5-6). One chromatid of the long X chromosome seemed to be longer than the other, with a thinning of the chromatin centrally in both chromatids (Figs 5-6).

Corasoides mouldsi (Fig. 7)

All chromosomes spreads examined were from Windsor Tableland, Qld and showed 23 pairs of autosomes and three X chromosomes (Fig. 7). *i.e.* 2N = 49. The relative size of the X chromosomes could not be determined.

Corasoides occidentalis (Figs 8-10)

Photographs of chromosome spreads were examined of specimens from various locations in WA, *i.e.* Stokes River National Park (Fig. 8), Fitzgerald River National Park, Corrigin, Gelorup, Glenforrest, Nanup, Stirling Ranges (Fig. 9), Cervantes (Fig. 10) and outside Jewel Cave. These all showed 23 pairs of autosomes and three X chromosomes with a definite designation of the X chromosomes into two long and one shorter in length (Figs 8-10). A parallel association of the X chromosomes was sometimes observed (Fig. 9).

Corasoides australis (Figs 11-14)

Chromosome spreads from multiple specimens were examined from Fraser Island, Blackdown Tablelands (Qld), Sydney (NSW), from Morgan, Wilpena Pound, Port Lincoln, Streaky Bay and Nullabor (SA) and from Coolgardie and Collie (WA). In *C. australis* there are 23 pairs of chromosomes and three sub-equal X chromosomes *i.e.* 2N = 49.

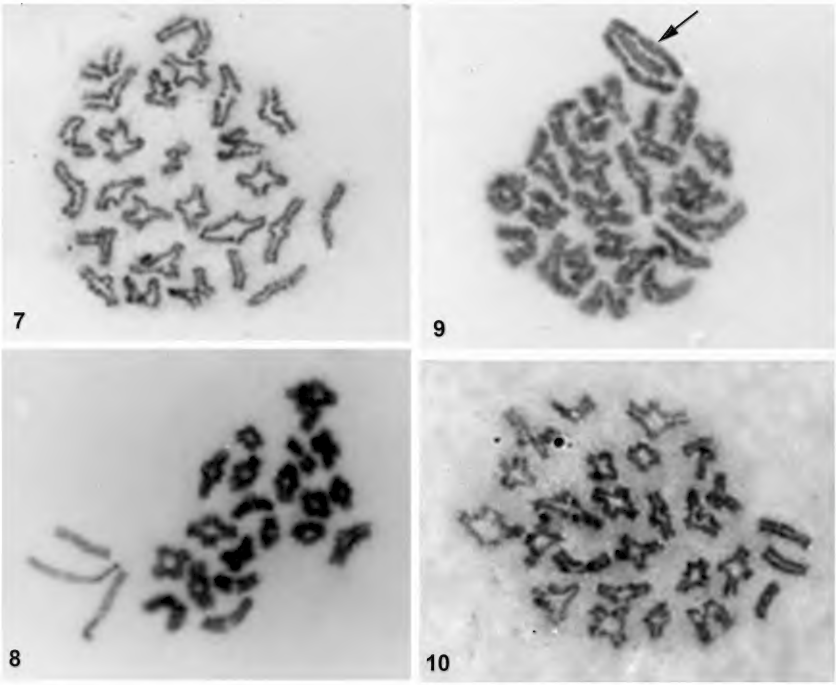
Embryos

Because of poor spreading of the chromosomes, most mitotic cells could not be counted with confidence. Of nine countable cells recorded of *Corasoides australis*, seven had 52 chromosomes and two had 49, which is consistent with a 2N = 49, X_1,X_2,X_3 male and 2N = 52, $X_1X_1X_2X_2X_3X_3$ female. The number of cells counted was too few to be able to determine the sex ratio.

Conclusion

Male spiders of *Corasoides terania, C. mouldsi, C. occidentalis* and *C. australis* were examined cytogenetically and found to have a 2N = 49, which included three X-chromosomes. Females of *C. australis* had 2N = 52, which can be presumed to include six X chromosomes.

Corasoides terania, *C. occidentalis* and *C. australis* can be distinguished from each other by the relative lengths of their X chromosomes, namely *C. terania* with one long and two short, *C. occidentalis* with two long and one short and *C. australis* with three sub-equal.



Figs 7-10. *Corasoides* spp. male meiosis. X chromosomes are placed at the periphery of the plates: (7) Diplotene spread of specimen of *C. mouldsi* from Windsor Tableland, Qld showing 23 pairs of autosomes and three X chromosomes. The latter do not show as much difference in length as the sex chromosomes of *C. terania*; (8-10) *C. occidentalis*: (8) Diakinesis spread from Stokes River National Park, WA showing 23 pairs of autosomes and three elongate X chromosomes (lower left); (9) Diplotene spread from Stirling Ranges, WA showing 23 pairs of autosomes and three sex chromosomes in parallel association (arrowed); (10) Diplotene spread of male from Cervantes, WA showing 23 pairs of autosomes and three sex chromosomes, two long and one short.

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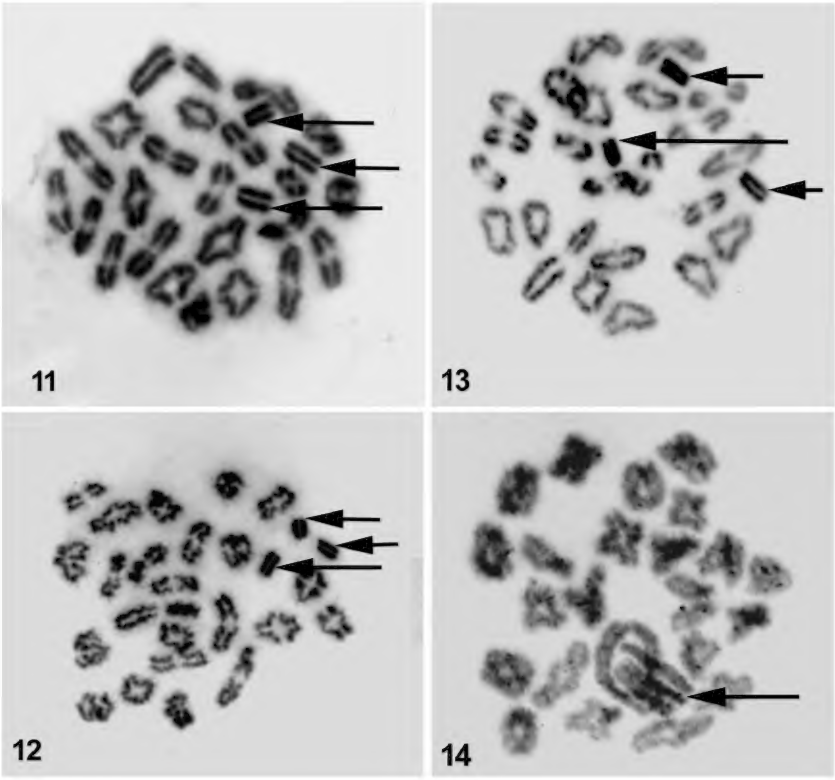

Figs 11-14. *Corasoides australis*, male meiosis (all showing 23 pairs of autosomes and three X chromosomes, arrowed): (11) Metaphase I spread from specimen from Port Lincoln, SA; (12) spread from specimen from Streaky Bay, SA; (13) Metaphase I spread from specimen from Morgan, SA; (14) spread (diplotene/diakinesis) from specimen from Fraser Island, Qld showing parallel association of the three sex chromosomes encircled by a long, metacentric chromosome.

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FIVE NEW BUTTERFLY LIFE HISTORIES (LEPIDOPTERA) FROM CHRISTMAS ISLAND, AUSTRALIA

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Abstract

The immature stages of *Appias olferna* Swinhoe, *Eurema blanda blanda* (Boisduval), *Euploea climena macleari* (Butler), *Hypolimnas anomala anomala* (Wallace) and *Jamides bochus* (Stoll) are described from Christmas Island, Indian Ocean, Australia. The larval food plants are *Cleome rutidosperma* DC for *A. olferna*; *Caesalpinia bonduc* (L.) Roxb. and *Pithecellobiun dulce* (Roxb.) Benth. for *E. blanda blanda*; *Hoya aldrichii* Hemsl. for *E. climena macleari*; *Pipturus argenteus* (G.Forst.) Wedd var. *lanosus* Skottsb. for *H. anomala anomala* and *Canavalia cathartica.*Thouars. for *J. bochus*. Eggs of *A. olferna* were laid singly on the underside of young leaves of the food plant, an introduced scrambling herbaceous weed that occurred in disturbed areas along roads and tracks in the forests. Eggs of *E. blanda blanda* were found in clusters of 20-50 or more on young leaves or occasionally stems of the food plants; larvae were gregarious throughout the lifecycle and pupation usually occurred on the bare terminal stems where all leaves had been consumed. The life history of *E. climena macleari* is described for the first time, with eggs laid singly underneath the young leaves of the food plant and larvae feeding exclusively on young leaves and shoots. Although male *E. climena macleari* butterflies were widespread, females were restricted to the forests where the food plant grew. The occurrence of *E. climena macleari* on the Australian mainland as vagrants from Christmas Island or Indonesia is supported by the absence of the food plant in NW Western Australia. Eggs of *H. anomala anomala* were laid *en masse* (300-500) underneath the young leaves of the food plant where the female butterfly would often be seen 'guarding' the egg mass; immature larvae skeletonised the leaf from the leaf tip, gradually extending the feeding to the petiole, while mature larvae consumed the whole leaf and larvae did not consume their shed exuviae after each moult. Eggs of *J. bochus* were laid singly or, more commonly, in groups of two to four, mainly on flower buds and occasionally on the flower pedicel of the food plant, each egg covered with a 'bubbled' gelatinous mass. The influence of the introduced yellow crazy ant (*Anoplolepis gracilipes* (Smith)) on the lifecycles described is also discussed.

Introduction

Christmas Island, at latitude 10°25'S and longitude 105°43'E, is located in the Indian Ocean 2650 km northwest of Perth, Western Australia and 380 km south of Java. Christmas Island covers 135 km^2, of which approximately 60% has been declared as National Park (Fig. 1). Average annual rainfall is 2670 mm.

Tall rainforest, with a canopy height to 40 m, grows over most of the plateau and terraces where soils are deep. Semi-deciduous forest, with a canopy height of 15-30 m, grows on the shallower soils of the slopes and terraces. Smaller areas of deciduous scrub occur on the steep slopes and inland cliffs. Introduced weeds occupy most of the disturbed mined areas and road corridors. Active rehabilitation of mined areas in areas of high ecological significance is being undertaken by Parks Australia staff.

The authors visited the island from 7-18 March 2017, with the primary aims of documenting the butterfly life cycles that were unknown or not recorded in Australia and to undertake a survey of the occurrence, relative abundance and distribution of the butterflies on the island. The results of the survey will be presented in another paper. The influence of the introduced yellow crazy ant (*Anoplolepis gracilipes* (Smith)) on butterfly life histories was also assessed.

Fig 1. Map of Christmas Island (Source: Christmas Island National Parks, Parks Australia).

Deficiencies in the life history descriptions and duration of many of the larval instars and pupa stages was due to the short time on the island, the strict quarantine regulations prohibiting the import of live insect material into Australia and the fact that observations were often based on a limited number of eggs and larvae.

Life histories

Family PIERIDAE

Appias olferna Swinhoe, 1890

(Figs 2-6)

Appias olferna is known from India, Laos, Myanmar, Vietnam, West Malaysia, Singapore, Sumatra, Java and Christmas Island (*http://yutaka.it-n.jp/pie/20220001.html*). Christmas Island is the only known Australian location for this species.

Figs 2-6. Immature stages and food plant of *Appias olferna* on Christmas Island: (2) egg; (3) final instar larva; (4) pupa dorsal view; (5) pupa lateral view; (6) food plant *Cleome rutidosperma.*

Lambkin and Knight (2004) first recorded *A. olferna* on Christmas Island in 2003.The life history is recorded from South-East Asia (Butterflycircle 2010) but within Australia territory the immature stages and the larval food plant were not recorded previously.

Egg (Fig. 2). Approximately 1 mm high, initially white in colour becoming yellowish orange within one day; spindle-shaped with longitudinal ribs and numerous lateral bands between the ribs.

First instar larva. Not recorded.

Final instar larva (Fig. 3). Length 30-35 mm; head and body green with numerous short tubercles; a faint whitish green lateral line below spiracles.

Pupa (Figs 4-5). Length 20-22 mm; cylindrical; pale green, attached by cremaster and girdle; a long pointed curved head projection, ventrally yellowish white, dorsally blackish purple; a prominent thoracic dorsal ridge,

blackish purple with two yellowish white patches; a prominent lateral ridge produced into a short spine on both sides of the abdomen on segment 2, colours similar to the thoracic ridge; two yellowish white lateral lines extend from segment 3 to the cremaster and a dorsal line of the same colour extends from the thoracic ridge to the cremaster; small black spots scattered over the thorax and a pair of similar spots on each abdominal segment.

Biological notes. Eggs were observed being laid singly on the underside of young leaves of *Cleome rutidosperma* DC. (Capparaceae: fringed spiderflower) (Fig. 6), an introduced scrambling herbaceous weed that occurs in disturbed areas along roads and tracks in the forest, preferring moister shaded areas. Eggs hatched in two days. Larvae consumed young to semi-mature leaves and young shoots. Mature larvae also consumed the stem and flowers. The larval period was 10 days.

Larvae pupated on the vertical stems and under leaves of the food plant. The pupal colour and shape matched the leaves and stems of the food plant.

Egg-laying was first observed on immature plants on the Greta Beach Road, where roadside disturbance had resulted in abundant seeding regrowth. *Appias olferna* was a very common species observed throughout the island. While male butterflies were widely dispersed, females were more abundant where the food plant grew in shaded areas along the side of roads and tracks in the forest.

Abundant eggs and several larvae were observed on most of the food plants, with larvae often defoliating isolated plants. The plant was abundant in moister areas along roads and tracks that were subject to regular mowing.

***Eurema blanda blanda* Boisduval, 1836**

(Figs 7-14)

Eurema blanda occurs extensively in the Indo-Australian region from India and Sri Lanka through South-East Asia to the Philippines, Moluccas and Papua New Guinea (Braby 2000, Parsons 1999). *Eurema blanda blanda* is widely distributed from the Malay Peninsula and Borneo, Sumatra and Java to Christmas Island (Braby 2000), while *E blanda saraha* (Fruhstorfer, 1912) is recorded in Australia from Dauan and Darnley Islands in Torres Strait (Wilson and Johnson 2016).

The species was first recorded on Christmas Island in 1985 (Moulds and Lachlan 1987) and the life cycle has been well documented from other countries (Parsons 1999). Parsons (1999) also described the immature stages of *E. blanda saraha* from Papua New Guinea but within Australia territory the immature stages and larval food plant are not recorded.

Egg (Figs 7-9). Approximately 1.3 mm high; white in colour, elongate with indistinct longitudinal ribs.

Figs 7-14. Immature stages of *Eurema blanda blanda* on Christmas Island: (7) eggs on young leaves of food plant *Caesalpinia bonduc*; (8) eggs on food plant *Pithecellobiun dulce*; (9) eggs on the stem of food plant *Caesalpinia bonduc*; (10) first instar larvae; (11) final instar larvae; (12) cluster of pupae; (13) variation in pupal colour and markings; (14) pre-emergence pupa.

First instar larva (Fig. 10). Body initially whitish when first hatched after eating the egg shell then becoming yellowish green after consuming the leaves of the food plant; lateral rows of tubercles cover the body; head dark brown.

Final instar larva (Fig. 11). Length approximately 26 mm; cylindrical; body yellowish green to green with lateral rows of numerous setae bearing tubercles which were more prominent than in younger larva; head black.

Pupa (Figs 12-14). Yellowish green to green through to dark brown with variable markings; distinctly 'keeled' ventrally; prominent pointed horn on the head, white or tipped white on the brown pupa; secured by a cremaster and a silk girdle.

Biological notes. Eggs were found in clusters of 20-50 or more on young leaves or occasionally the stem of *Caesalpinia bonduc* (L.) Roxb. (Caesalpiniaceae) (Figs 7, 9) and less commonly on young leaves of *Pithecellobiun dulce* (Roxb.) Benth. (Fabaceae) (Fig. 8). Eggs hatched after 4 days with the larva initially eating the egg case before consuming the leaf. The larvae were gregarious throughout the life cycle. Pupation usually occurred on bare terminal stems where all leaves were consumed or on the leaf stems or amid mature leaves of the food plants. Pupal colour and markings were highly variable, ranging from yellowish green to dark brown, with brown coloration dominant and matching dead leaves and stems of the food plant. The bright yellow colour of the wings of pre-emergence pupae made them obvious (Fig. 14).

Parsons (1999) reported *Albizia* and *Cassia* species as food plants in the Indian Subregion and in Papua New Guinea. Although *Cassia fistula* L. and other *Cassia* species occurred in urban areas on Christmas Island, immature stages of *E. blanda blanda* was not observed on these plants.

Eurema blanda blanda was abundant over the island, particularly on the northern side of the island where the food plant was common. Females were often observed flying around the food plants. Adults were observed on several occasions massing at water seeps at 'The Grotto' and beside the road on the northeastern side of the island.

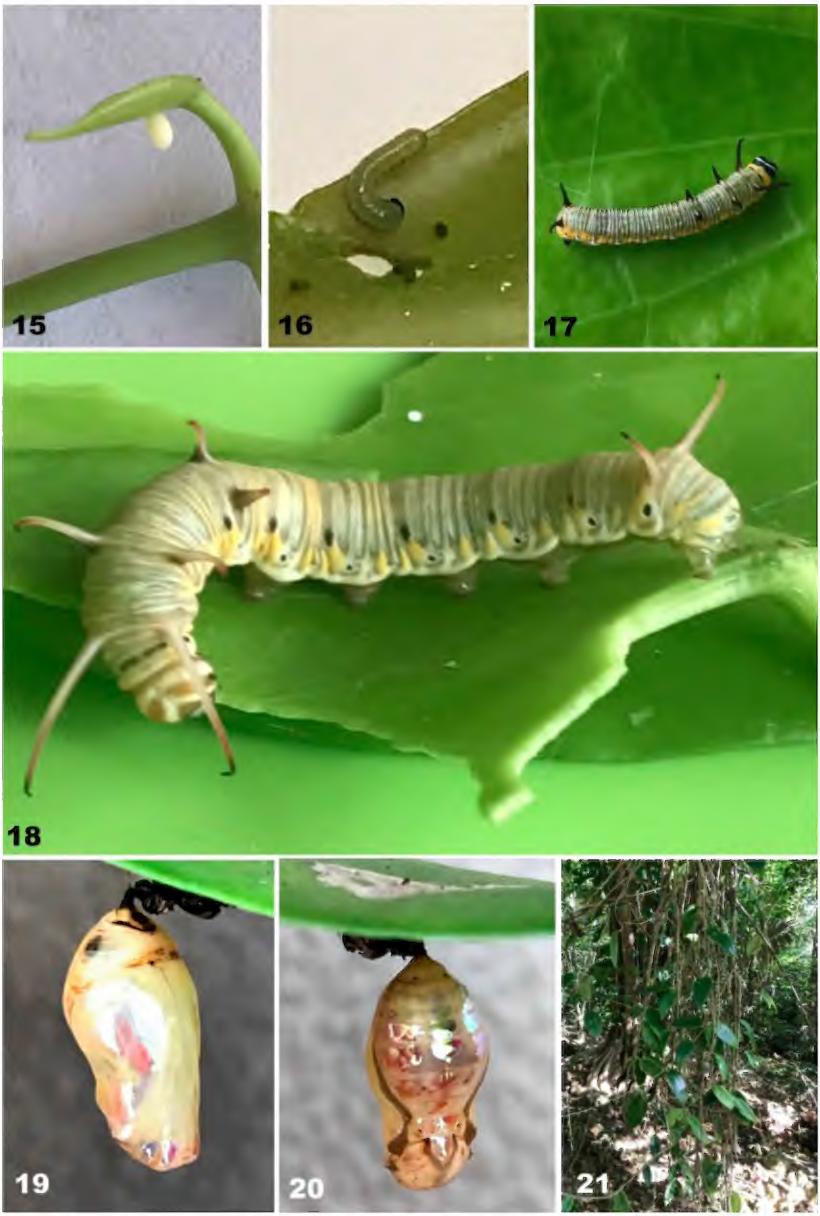
Caesalpinia bonduc is an evergreen vine or climbing shrub with numerous thorns on the stems and leaves. The plant was particularly common on the coastal terraces (Claussen 2005) on the north and northeastern sides of the island. Many eggs and larvae were located on immature leaves of both food plants. Seedlings of the Class 1 declared weed species *Pithecellobiun dulce* (Madras thorn) were reported to the Park Australia staff for eradication.

Family NYMPHALIDAE

***Euploea climena macleari* Butler, 1887**

(Figs 15-21)

Euploea climena Stoll is known from Indonesia, where it ranges from Sumatra to Ceram and the Kai Islands, and in Christmas Island and Western Australia. Christmas Island and the northwestern mainland of Australia are the only known Australian localities of *E. climena macleari*, where it is reported to favour damp shady habitats (Braby 2000).



Figs 15-21. Immature stages and food plant of *Euploea climena macleari* on Christmas I: (15) egg; (16) first instar larva; (17) semi mature larva; (18) final instar larva; (19) pupa lateral view; (20) pupa dorsal view; (21) food plant *Hoya aldrichii*.

Moulds and Lachlan (1987) recorded *E. climena macleari* in January and March and from July to November. The immature stages and larval food plant were unknown previously from Indonesia and Australia.

Egg (Fig. 15). 1.5 mm high, approximately 0.8 mm wide; pale creamy white becoming creamy yellow prior to hatching; elongate; surface covered with very shallow pits.

First instar larva (Fig. 16). Cylindrical; body pale yellow when first hatched, becoming green after consuming the food plant; each segment with very pale transverse bands; a pair of very short and inconspicuous black fleshy filaments on mesothorax, metathorax and 2nd and 8th abdominal segments; head black.

Semi-mature larva (Fig. 17). Cylindrical; body green; each segment from mesothorax to the 8th abdominal segment with green transverse rings extended to the ventrum, interspersed with narrow white bands; a yellow-orange ventrolateral band; prominent black fleshy filaments on mesothorax, metathorax and abdominal segments 2 and 8 with the 2nd thoracic and 8th abdominal filaments significantly longer than the others; a short black band on the dorsum of the prothorax adjacent to a yellow band behind the head; head black with white markings forming an inverted 'V' anteriorly above labrum and an outer white transverse band; spiracles black; legs and prolegs black.

Final instar larva (Fig. 18). Length 40 mm; cylindrical; body grey-green with slightly broader grey-green transverse bands on thoracic and abdominal segment, each broader abdominal band on abdominal segments 2-8 with a ventrolateral black spot, interspersed creamy white bands, each band joined to a yellow disrupted dorsolateral band just above legs and prolegs; black tipped white fleshy filaments on mesothorax, metathorax and abdominal segments 2 and 8, the 2nd thoracic protuberance longer than the others; a short black band on the dorsum of the prothorax adjacent to a yellow band behind the head the same as earlier instars; head greenish brown with white markings the same as the semi-mature instars; spiracles black; ventral surface, legs and prolegs olive-green.

Pupa (Figs 19-20). Pupa initially yellowish brown, becoming silver with brown dorsolateral markings after one day.

Biological notes. Eggs were observed being laid singly underneath young leaves less than 30 mm long of *Hoya aldrichii* Hemsley (Apocynaceae) (Fig. 21). *Hoya aldrichii* is an endemic epiphytic vine common throughout the undisturbed forests of Christmas Island (Claussen 2005). Eggs hatched after 4 days, with the larva initially eating the egg case before consuming the leaf. Immature larvae up to approximately 10 mm long remained on the leaf where the egg was laid, then migrated to an adjacent immature leaf. Once the initial and adjacent immature leaves were consumed, larvae were observed

migrating considerable distances to find suitable food leaves or tips of shoots. The tough 'leathery' mature leaves had no signs of eating. During leaf consumption, milky sap exudate surrounded the damaged leaf area.

Pupae were not observed in the forest. In captivity, larvae pupated under mature leaves of the food plant. When several larvae were confined in a container they were cannibalistic, usually resulting in the largest larva surviving. Only single larvae were observed on stems of the food plant under natural conditions. This might be a normal survival mechanism as each stem of the food plant had a very limited number of immature leaves.

Euploea climena macleari was widespread, with males widely dispersed over the island and often seen feeding at flowering plants. Males were particularly common at Octopus Bush (*Heliotropium foertherianum* Diane & Hilger; formerly *Argusia argentea* (L. f.) Heine), often with up to eight butterflies on one leaf consuming the sap exudate from the 'salt and pepper moth' larvae (*Utetheisa lotrix* (Cramer, 1777) or *U. pulchelloides* Hampson, 1907: family Erebidae) feeding on the leaves. Healthy Octopus Bush, with no moth leaf-feeding, usually did not attract the butterflies. Females were restricted to the forests where the larval food plant occurred, rarely flying through open or disturbed areas.

Eleven eggs and four larvae were collected on immature leaves. Although the plant was abundant, immature leaves were uncommon and eggs or larvae were very uncommon during mid-March. The abundance of adults would suggest an earlier peak breeding season, possibly corresponding to the arrival of monsoonal rains over the summer months.

Braby (2000) suggested that *E. climena macleari* is unlikely to be established on the Australian continent. North of Derby in the Kalumburu area, *Hoya australis* R.Br. is a native plant on the sandstone hills and cliffs of the north Kimberley area of northwestern Western Australia (Florabase, Dept of Parks and Wildlife, WA). However, *E. climena* has not been recorded from this area. Therefore, the specimens recorded at Roebourne and Derby were likely to have been vagrants from Christmas Island or Indonesia, as *Hoya* has not been recorded from these mainland areas. As *Hoya aldrichii* is endemic to Christmas Island, other subspecies of *E. climena* presumably use other *Hoya* species as food plants.

***Hypolimnas anomala anomala* (Wallace, 1869)**

(Figs 22-30)

Hypolimnas anomala ranges from Taiwan, southern Japan, Philippines and Malaya through Indonesia and Christmas Island to northern Australia, where it occurs in rainforest (Braby 2000). Christmas Island is the only known Australian locality for typical *H. anomala anomala*. The subspecific status of the Australian mainland population has not been determined with certainty but it might be *H. a. albula* (Wallace) from Timor and Babar (Braby 2000).

Figs 22-30. Immature stages and food plant of *Hypolimnas anomala anomala* on Christmas Island: (22) eggs; (23) 400-500 egg mass; (24) first instar larvae; (25) gregarious second instar larvae on a partially skeletonised leaf; (26) gregarious final instar larvae; (27) final instar larva; (28) pupa dorsolateral view; (29) pupa dorsal view; (30) food plant *Pipturus argenteus* var. *lanosus* almost defoliated by larvae.

Hypolimnas anomala anomala was first reported on Christmas Island in 1932 by Pendlebury (1933). Moulds and Lachlan (1987) recorded it in all months, being very plentiful in January, and also reported extensive parasitisation of the pupae.

The life history is recorded from South-East Asia (Butterflycircle 2011) but was previously unknown within Australian limits.

Egg (Fig. 22-23). Approximately 0.7 mm high and 0.5 mm wide; yellow; globular with nine longitudinal ribs and numerous inconspicuous horizontal bands.

First instar larva (Fig. 24). Length 3-4 mm before moulting; body initially yellow, becoming greenish brown on the anterior end and yellow on the posterior end after consuming the food plant; body cylindrical, covered with numerous small black tubercles and long black setae protruding from the tubercles; head black with no visible horns.

Final instar larva (Figs 26-27). Length 50 mm; body black with numerous lateral rows of branched yellow-orange spines; head dark brown with two long black branched spines (Fig. 26).

Pupa (Figs 28-39). Brown with several rows of black to dark brown dorsal and dorsolateral spines, dorsal spines larger than the lateral ones; dark brown veins on the wing cases.

Biological notes. Eggs were observed being laid en masse (300-500) underneath young leaves of *Pipturus argenteus* var. *lanosus* (Skottsb.) (Urticaceae) (Figs 22-23), a small evergreen tree or shrub to 8 m high, common in the forests on the terraces and plateau and disturbed areas (Caussen 2005). Females were often seen 'guarding' the egg masses. Eggs hatched after 4 days and the larva initially ate the egg case before feeding on the leaf. Larvae were gregarious throughout the larval stages (Figs 25-26). Immature larvae skeletonised the leaf from the leaf tip, gradually extending the feeding to the petiole (Fig. 25). Skeletonised, curled leaves tend to remain silked to the tree. Mature larvae consumed the whole leaf (Figs. 26), which often resulted in defoliation of smaller shrubs (Fig. 30). Final instar larvae then migrated off the tree to pupate elsewhere and were seen walking over leaf debris, sticks and logs on the ground or other plants. The omnivorous robber crabs showed no interest in the larvae.

The larva did not consume their shed exuvia after each moult, resulting in numerous shed exuviae remaining on the leaf. Pupae were not able to be located in the forest. In captivity, larvae pupated on leaf petioles, stems and under leaves.

Hypolimnas anomala anomala was widespread and abundant, being the most common butterfly observed on the island. Many thousands of eggs and larvae at various stages were observed. The very abundant immature stages suggested a mass emergence of adults after our visit in March or subsequent severe parasitisation as recorded by Moulds and Lachlan (1987).

Braby (2000) stated that the food plant is unknown in northern Queensland and the Northern Territory. *Pipturus argenteus* (false stinging tree) occurs on Cape York Peninsula and in the Northern Territory where the butterfly has been recorded.

Family LYCAENIDAE

***Jamides bochus* Stoll, 1782**

(Figs 31-35)

Jamides bochus ranges from India, Sri Lanka, Thailand, eastern China, Taiwan, Hong Kong, Philippines and the Malay Peninsula through parts of Indonesia to New Guinea (Braby 2000, Parsons 1999). Christmas Island is the only known Australian locality of this species and the subspecific status of the population is uncertain.

Moulds and Lachlan (1987) first recorded the species on Christmas Island in 1985. Bell (1918) described in detail the early stages of *J. bochus* from India and Parsons (1999) described its immature stages from Papua New Guinea but within Australia territory the immature stages and larval food plant were not recorded previously.

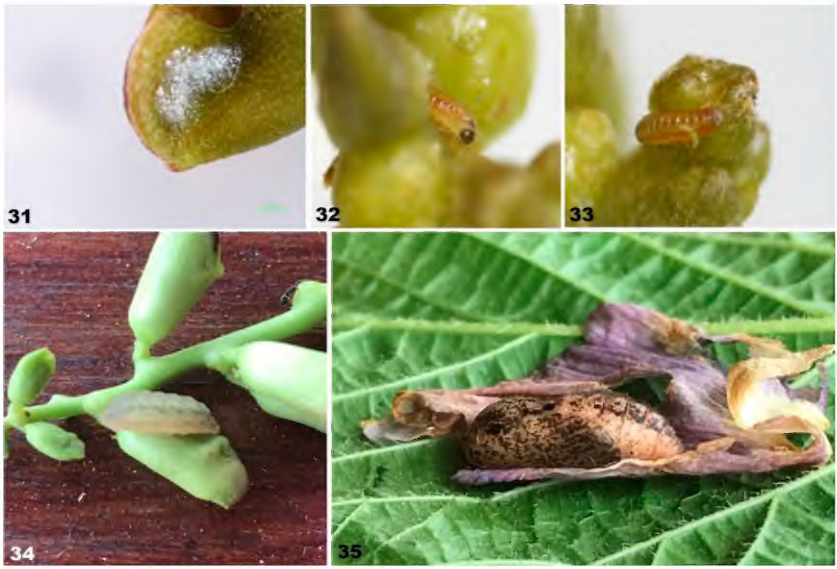
Egg (Fig. 31). Approximately 0.5 mm in diameter; pale green; mandarin-shaped, broader than high, covered with a fine reticulated pattern that is difficult to see through the 'bubbled' gelatinous mass deposited over them.

First instar larva (Figs 32-33). Length approximately 1-1.5 mm; body pale yellow initially becoming greenish yellow after feeding on the food plant; numerous pink dorsal spots and numerous pink lateral markings forming a discontinuous lateral band; numerous long setae with a dark base; dark area dorsally on the prothorax; head dark brown.

Final instar larva (Fig. 34). Length 9-10 mm; body greyish green to pale pinkish brown, covered with numerous short fine setae; darker dorsolateral and lateral lines; the dark area dorsally on the prothorax present on the earlier instars was no longer visible; the dorsal nectary organ not easily visible.

Pupa (Fig. 35). Length 10 mm; pale brown to beige with numerous brown and some black markings, especially on the wing cases and dorsally.

Biological notes. Eggs were observed being laid singly or, more commonly, in groups of 2-4, mainly on flower buds and occasionally on the flower pedicel, each egg covered with a 'bubbled' gelatinous mass (Fig. 31). The food plant was *Canavalia cathartica* Thouars (Fabaceae), a scrambling vine with large bright pink pea flowers, common over the whole island but particularly abundant on the northern and northeastern sides and at South Point (Claussen 2005). Eggs hatched in three days and larvae consumed part of the egg before burrowing through the gelatinous mass and into the flower buds.



Figs 31-35. Immature stages of *Jamides bochus* on Christmas Island: (31) four eggs on young flower buds of *Canavalia cathartica*; (32-33) first instar larva; (34) final instar larva; (35) pupa.

Active consumption of the gelatinous mass was not observed and immature larvae were rarely seen, spending most of their time within the flowers.

Mature larvae were observed head down in the sepals, consuming the ova and very immature pods and, occasionally, semi-exposed and consuming the petals.

Pupae were not found on the plant and would be expected to pupate in curled or dead leaves. In captivity, some newly collected final instar larvae pupated in the petals of the food plant (Fig. 35) but most pupated off the plant.

Parsons (1999) recorded a large number of food plants, including *Millettia pinnata* (L.) (formerly *Pongamia pinnata*), which was relatively common in other parts of the island where *J. bochus* was observed and collected.

Male butterflies remained relatively high in the canopy, patrolling the edge of the forest. Females were particularly abundant around the food plant from early to mid-morning. Many eggs and larvae were found on flower buds and mature flowers and eggs were particularly abundant. Partially consumed flowers containing a larva or larvae were often detached from the flower stem but remained semi-attached by silk.

Discussion

The life histories of *A. olferna, E. blanda, H. anomala* and *J. bochus* are consistent with those described in other countries. However, the colour patterns of *A. olferna* pupae are slightly different from the subspecies described from South-East Asia. The subspecific status of *A. olferna* and *J. bochus* populations on Christmas Island remain uncertain.

The larval stages of *E. climena macleari* are characteristic of other *Euploea* species except for the dramatic colour change of the fleshy filaments on the mesothorax, metathorax and abdominal segments 2 and 8, from black in the immature instars to white in the final instar. The cannibalistic nature of the larvae appears to be a characteristic survival mechanism when the food plant is scarce. Of the many hundreds of food plants observed, very few had immature leaves, usually with one or two or rarely three immature leaves. Of the few larvae found, there was never more than one larva per stem.

Adult flight activity of the species recorded here remained constant through the day form mid-morning to late afternoon while conditions were warm and sunny, with adult butterflies often seen feeding at flowers. Only *H. anomala* and *E. climena* were seen flying during cloudy or rainy conditions. Adults of *A. olferna, E. blanda, H. anomala* and *E. climena macleari* were usually seen flying within two metres of the ground and females were observed more commonly where the food plants occurred. Males of *J. bochus* remained relatively high in the canopy, patrolling the edge of the forest in sunny patches throughout the day and rarely descending below 4-5 metres from the ground. Females were particularly abundant around the food plant early to mid-morning, often descending to ground level.

The butterfly populations of all species for which life histories are described were healthy under current National Park management. Outside the National Parks on Crown Land butterfly populations were also healthy, particularly where food plants occurred. Areas subject to mining, past and present, were depauperate of host plants and butterfly activity. *Appias olferna* was noticeably abundant around its food plant, especially along road corridors where the seeds were spread by regular mowing and road maintenance.

The introduced pest yellow crazy ants (*Anoplolepis gracilipes*) has caused a rapid, catastrophic shift in the rain forest ecosystem with dramatic effects on the endemic red crab (*Gecarcoidea natalis* Pacock, 1888) population and forest dynamics where ‘super’ colonies of ants occurred (O’Dowd *et al.* 2003). The yellow crazy ant, which occurs over the whole island and despite close contact with immature stages, was not seen interfering with those of *A. olferna, E. blanda blanda, E. climena macleari* or *H. anomala anomala* when the ant was in low densities. Under these low ant densities the ants were seen attending the larvae of *J. bochus*, presumably collecting the exudate from the nectary organs, but there was no evidence of predation.

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